Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

JULY 1951

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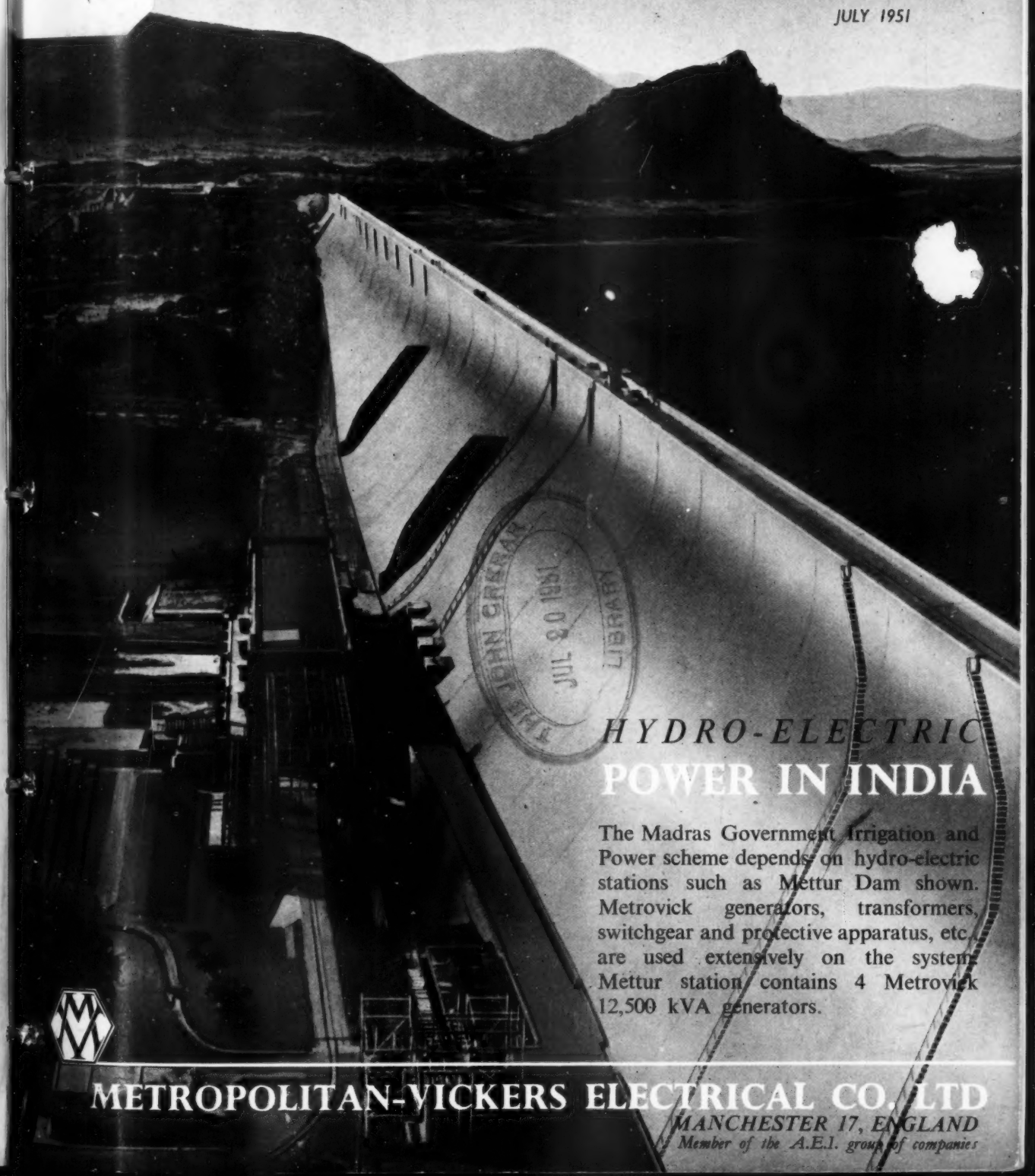
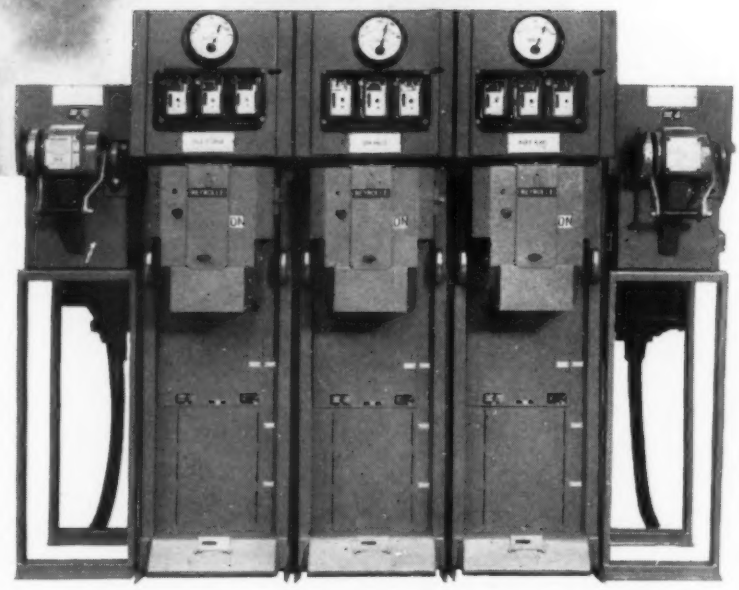


HYDRO-ELECTRIC
POWER IN INDIA

The Madras Government Irrigation and Power scheme depends on hydro-electric stations such as Mettur Dam shown. Metrovick generators, transformers, switchgear and protective apparatus, etc., are used extensively on the system. Mettur station contains 4 Metrovick 12,500 kVA generators.

METROPOLITAN-VICKERS ELECTRICAL CO. LTD
MANCHESTER 17, ENGLAND
Member of the A.E.I. group of companies

VICTORIA FALLS
Southern Rhodesia



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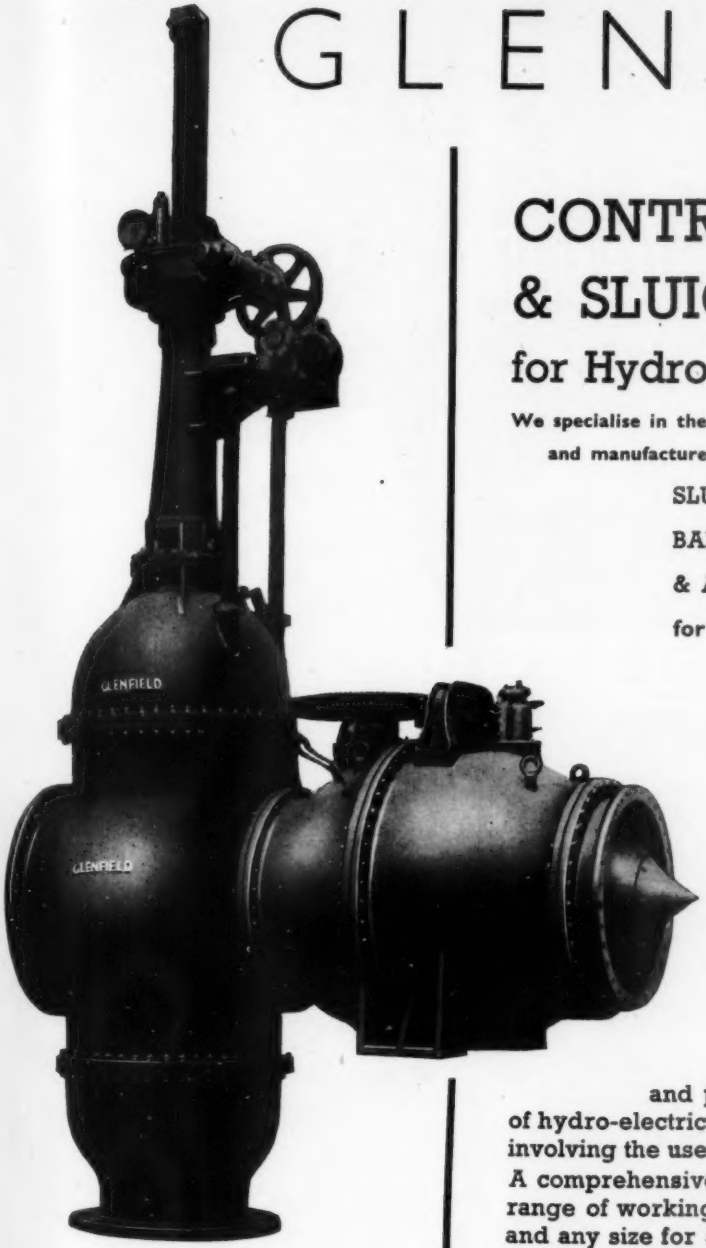

CONTROL VALVES & SLUICE GATES

for Hydro-Electric Power Plants

We specialise in the design and manufacture of

SLUICE VALVES
BALANCED DISC VALVES
& ANTI-VACUUM VALVES
for pipelines

NEEDLE VALVES
& JET DISPERSERS
or positions of free discharge

SLUICE GATES
DRUM GATES
& TILTING GATES
for headworks

and place our experience at the disposal of hydro-electric power plant engineers in all matters involving the use of these equipments.

A comprehensive range of sizes and types for a wide range of working heads has already been developed, and any size for any working head is almost certainly possible of development.

The illustration shows a mechanically operated needle valve guarded by a motor operated follower ring type Sluice Valve for a free discharge application—a jet disperser is incorporated in the design of the Needle Valve for the safe dissipation of the issuing stream.

We solicit and welcome enquiries.

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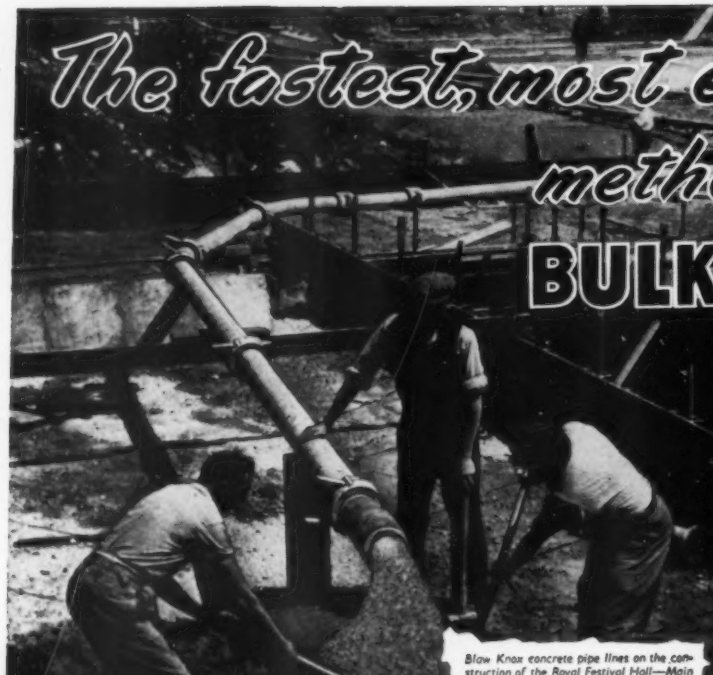


Blaw Knox concrete pipe lines on the construction of the Royal Festival Hall—Main Contractors—Messrs. Holland & Hannen and Cubitts Ltd.

BETTER
placing of high quality concrete at the lowest cost per cubic yard.

BETTER
placing on awkward sites—uphill, downhill and underwater . . . traversing highways and railway tunnels without obstructing traffic.

BETTER
placing without rehandling problems . . . no chutes, hoists, towers, buckets, cranes, etc.

BETTER
utilisation of man-power—with one man more concrete can be placed than by a whole team using old fashioned methods.

PUMP IT

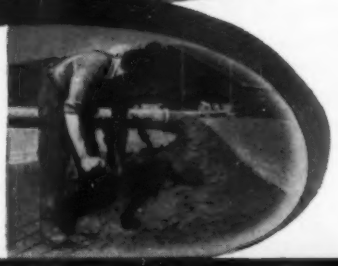
Basic component of the system is the **BLAW KNOX** portable, two speed, heavy duty, single acting horizontal piston pump. Capacity 15-20 cubic yards of concrete per hour.

PIPE IT

BLAW KNOX Concrete Pipelines comprise 6" steel pipes in various lengths up to 10' and simple, quick-acting couplings with rubber seatings for fast assembly and dismantling. During pumping the pipeline is completely filled, concrete moving through in synchronous impulses in an excellent state of uniformity.

PLACE IT

Concrete is poured straight into the forms, exactly where it is needed.



Blaw Knox engineers will be glad to advise on the application of the Concrete Pump to specific jobs.

BLAW KNOX

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Telephone: Kensington 5151 **Telegrams: Blawnox, Southkens, London**

* * *

TANGANYIKA

The Pangani Scheme

The lower photograph shows two of the machines built by us. Three 3600 BHP and one 7200 BHP turbines are in service and a further 7200 BHP unit will shortly be installed. All are horizontal shaft Francis turbines, the larger sets being of the twin runner type. The whole of the design and construction of Pangani Scheme was executed by Messrs. Balfour, Beatty & Co. Ltd.

An impression of the Pangani Falls.

Boving

WATER POWER ENGINEERS

Head Office:
56, KINGSWAY, LONDON, W.C.2,

Branch Offices: Wellington, Druids Chambers, Woodward Street.
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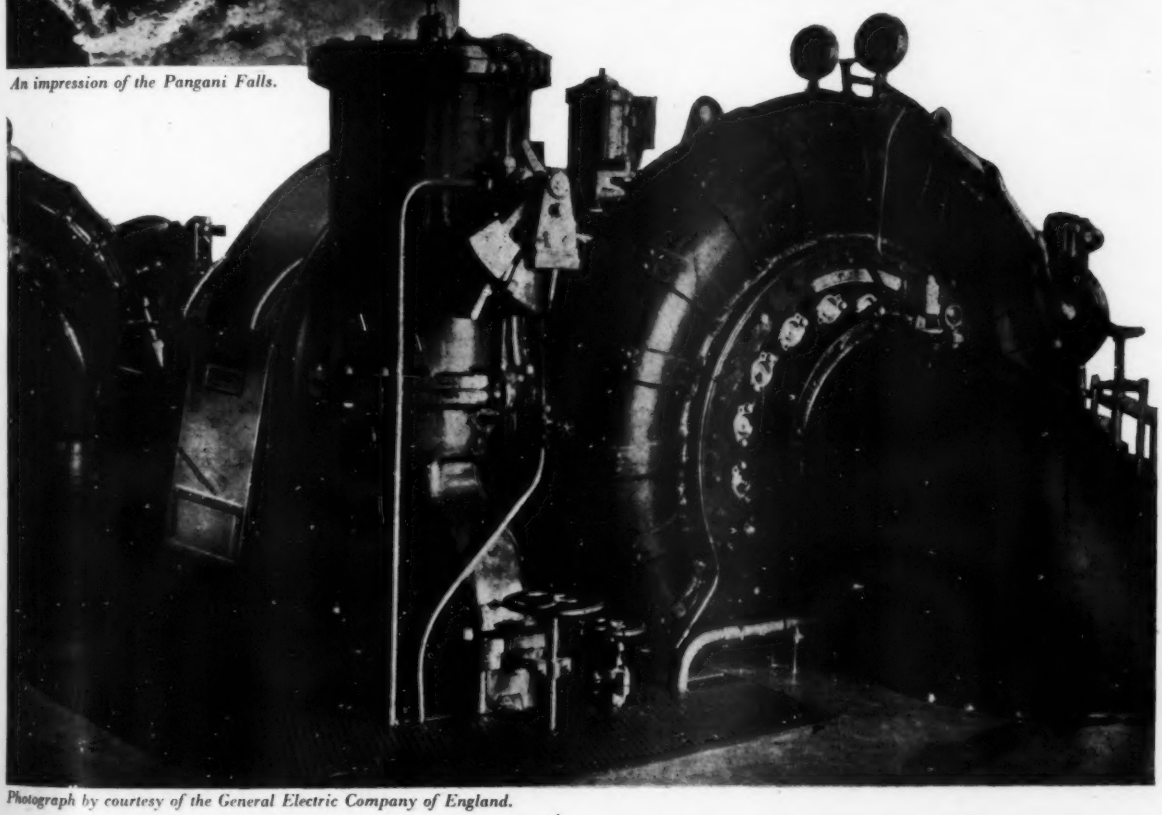
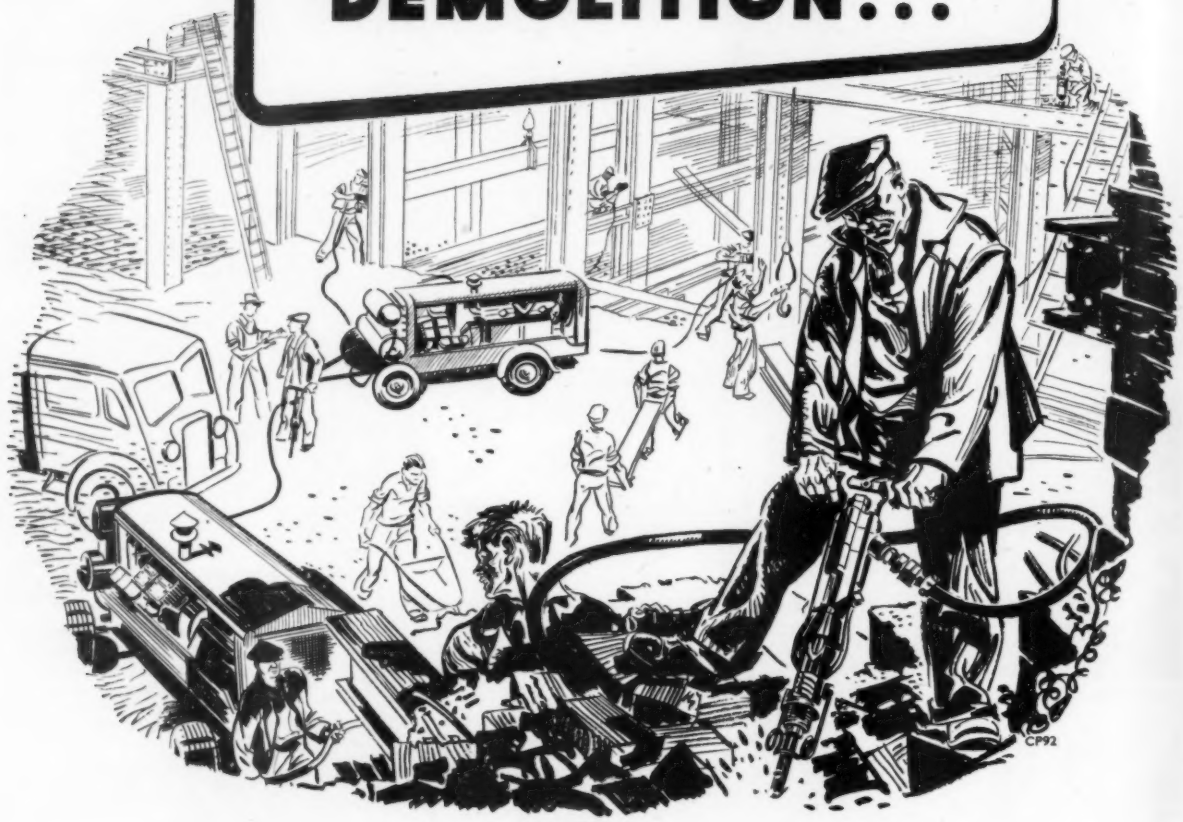
Calcutta: c/o Messrs. Macneill & Barry Ltd., 2 Fairlie Place.
Chittagong: (Pakistan) c/o Messrs. Macneill & Barry Ltd., Strand Road.



Photograph by courtesy of the General Electric Company of England.

FOR QUICKER DEMOLITION...



Get the preliminary work out of the way faster. CP demolition tools do more in less time . . . they put pneumatic power to its full use, eliminate waste effort, save man hours, reduce fatigue, and in themselves prove reliable over years of use with low maintenance costs. CP equipment for the contractor covers demolition tools, clay diggers, concrete vibrators, sump and sludge pumps, as well as a full range of portable compressors. You will get through to actual construction sooner when you . . .

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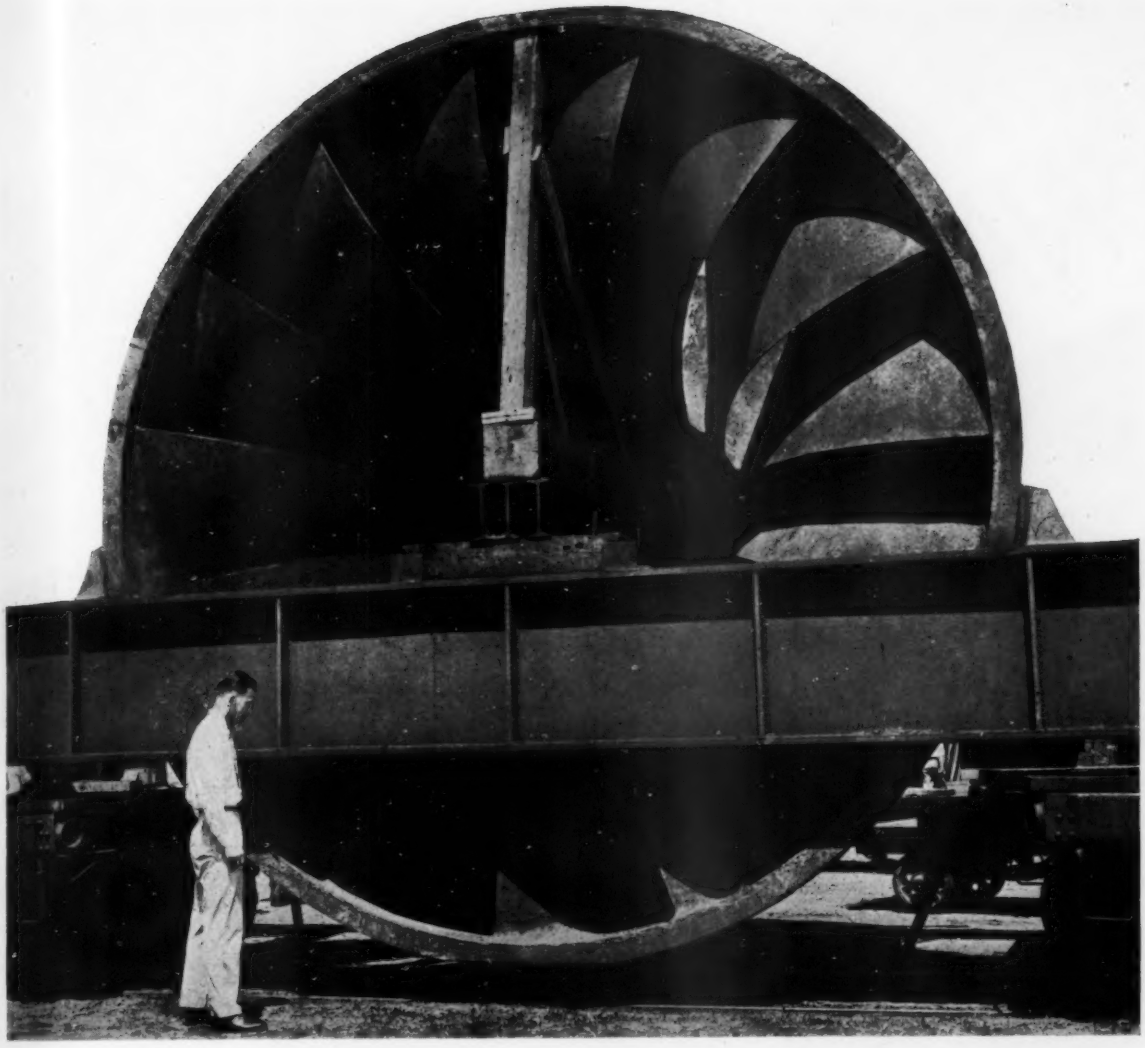

FACILITIES FOR THE SMALLEST OR LARGEST

The 225-acre Newport News plant includes plate steel and machine shops equipped with a complete variety of tools to fabricate items of water power equipment of any size. Contracts received by Newport News for hydraulic turbines with an aggregate rated output in excess of 7,000,000 horsepower have included units as high as 165,000 horsepower and as low as 500 horsepower.

Supplementing the extensive facilities are the equally important experienced and skilled personnel at Newport News to design and build such equipment.

Your inquiries for hydraulic turbines of any size will receive prompt attention.

Write for illustrated booklet on water power equipment.

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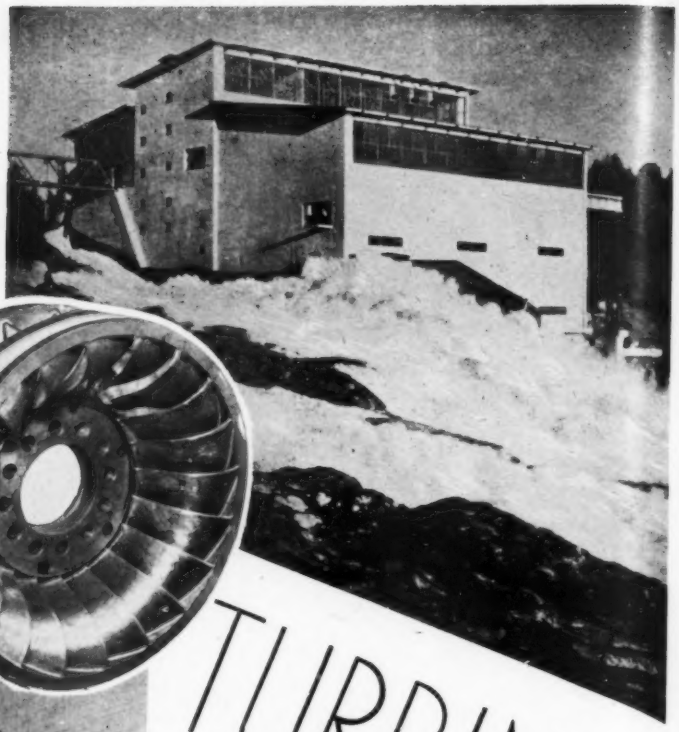
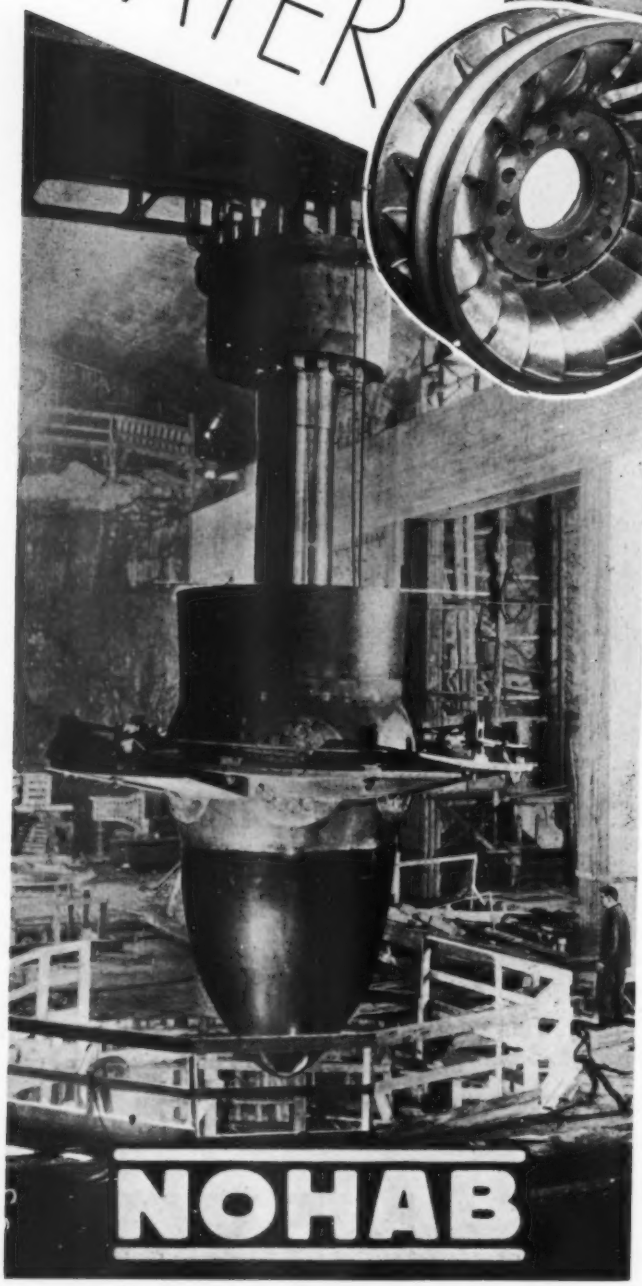
SHIPBUILDING AND DRY DOCK CO.

NEWPORT NEWS, VIRGINIA, U.S.A.

WATER TURBINES





GOVERNORS

CONTROL VALVES, GATES

AND OTHER EQUIPMENT FOR HYDRO-ELECTRIC POWER . . .

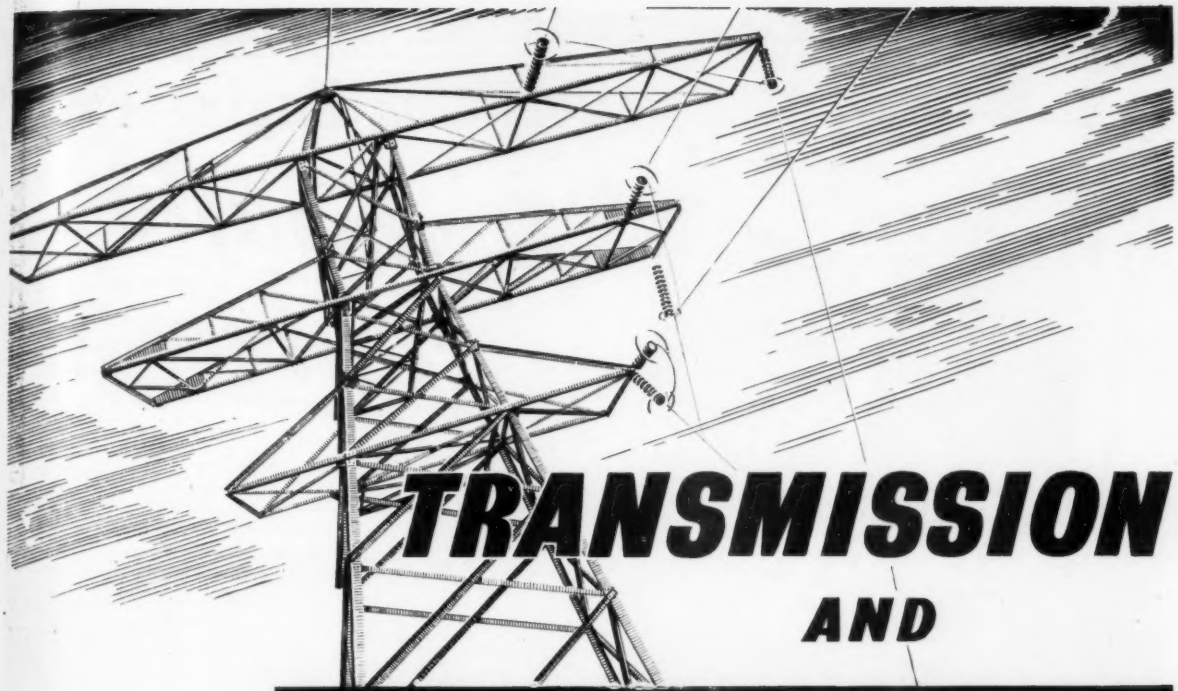
THE illustration shows a Kaplan runner 17½ ft. in diameter, being placed in position on site. Capacity 70,000 h.p. at a net head of 101 ft.

ONE Francis turbine with an output of 133,000 h.p. has recently been delivered to the Swedish State power station Harsprånget. A second turbine of the same capacity is now under erection in the same plant.

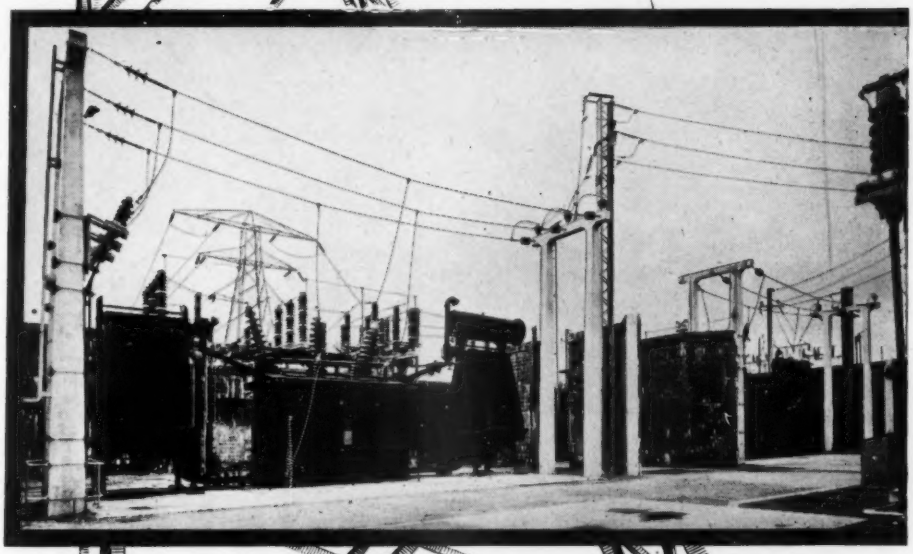
NOHAB

NYDQVIST & HOLM AKTIEBOLAG, Trollhättan, Sweden

Telegrams: Nohab, Trollhattan Codes: ABC 6th ed., Bentley's



TRANSMISSION AND TRANSFORMERS



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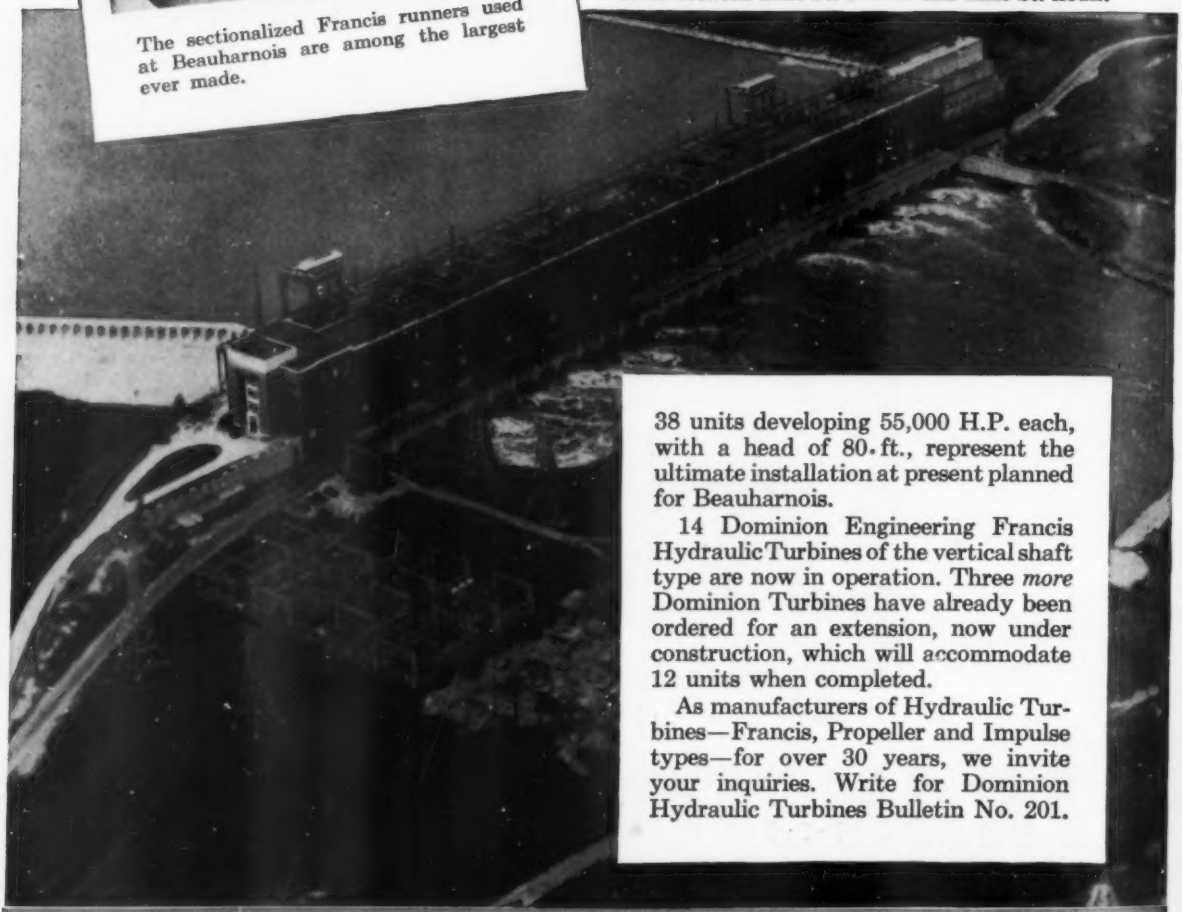
Ultimate Development of over 2,000,000 H.P. in one Canadian Plant

Dominion Engineering

Hydraulic Turbines

The sectionalized Francis runners used at Beauharnois are among the largest ever made.

The Quebec Hydro Electric Commission controlled power installation at Beauharnois near Montreal, at the down stream end of the 15 mile long, three quarter mile wide canal between Lake St. Francis and Lake St. Louis.



38 units developing 55,000 H.P. each, with a head of 80-ft., represent the ultimate installation at present planned for Beauharnois.

14 Dominion Engineering Francis Hydraulic Turbines of the vertical shaft type are now in operation. Three *more* Dominion Turbines have already been ordered for an extension, now under construction, which will accommodate 12 units when completed.

As manufacturers of Hydraulic Turbines—Francis, Propeller and Impulse types—for over 30 years, we invite your inquiries. Write for Dominion Hydraulic Turbines Bulletin No. 201.

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We make Transformers to suit all requirements up to 45,000 k.V.A. - 132,000 volts.

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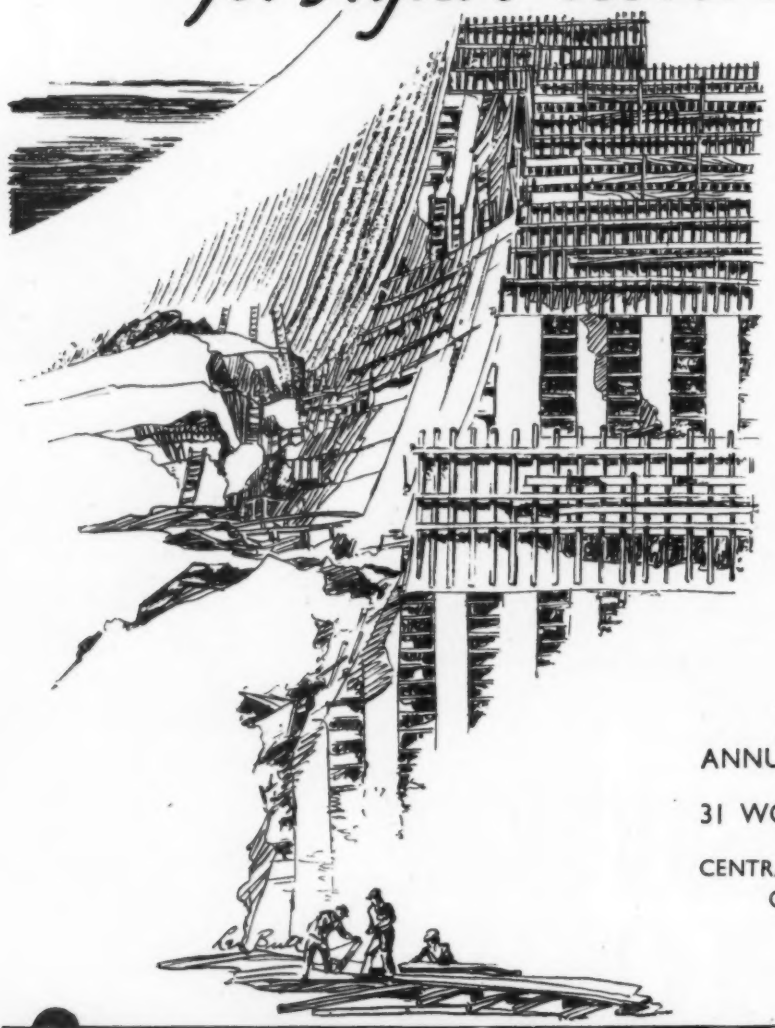
for Hydro-electric schemes



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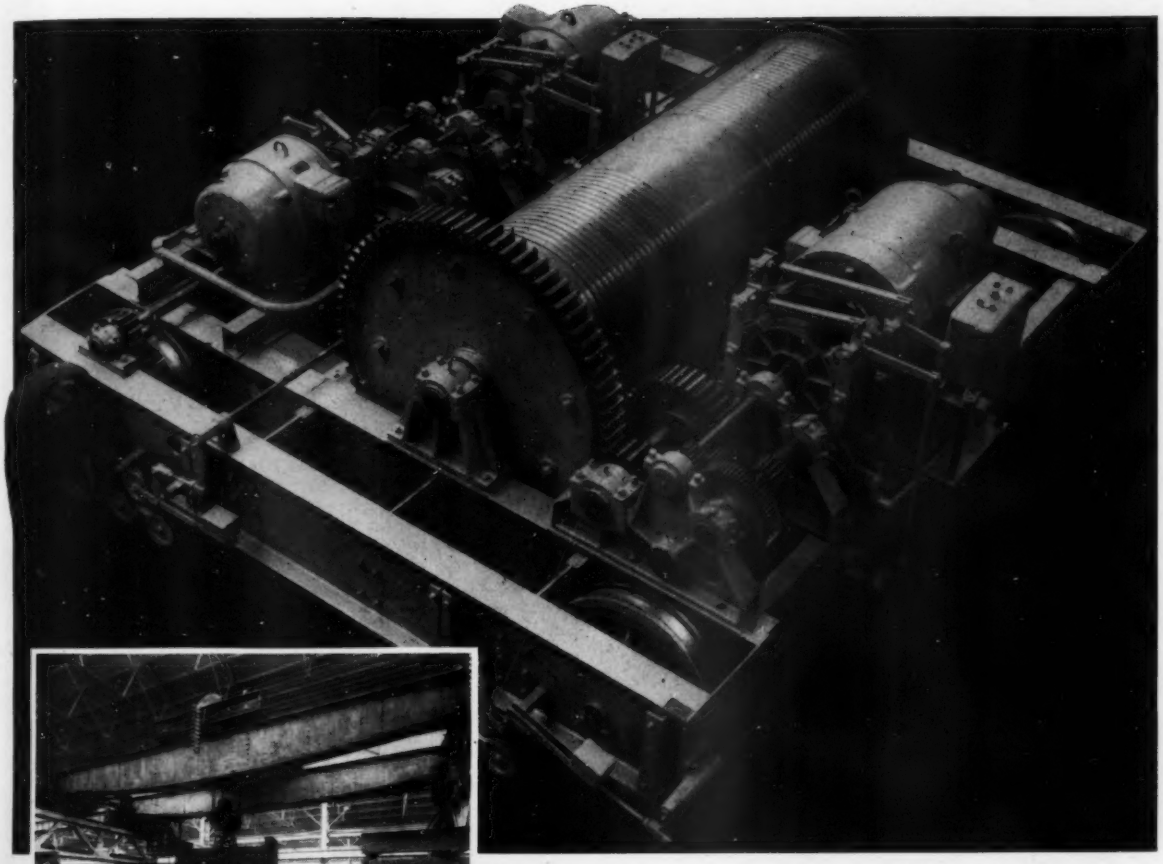
Cranes for the power station



SHOWN above is the crab of a Morris crane for a hydro-electric power station. On the right is the main 110-ton hoisting gear. Behind the drum is the auxiliary hoist, which, in this instance, lifts loads up to 10-tons. To the left is the gear for traversing the crab to and fro across the crane bridge. The inset shows the complete crane being tested with the full load. Afterwards the test load was increased to 165-tons, that is 50 per cent overload.

MORRIS

HERBERT MORRIS LTD., LOUGHBOROUGH, ENGLAND

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54 VICTORIA STREET, LONDON

GILKES

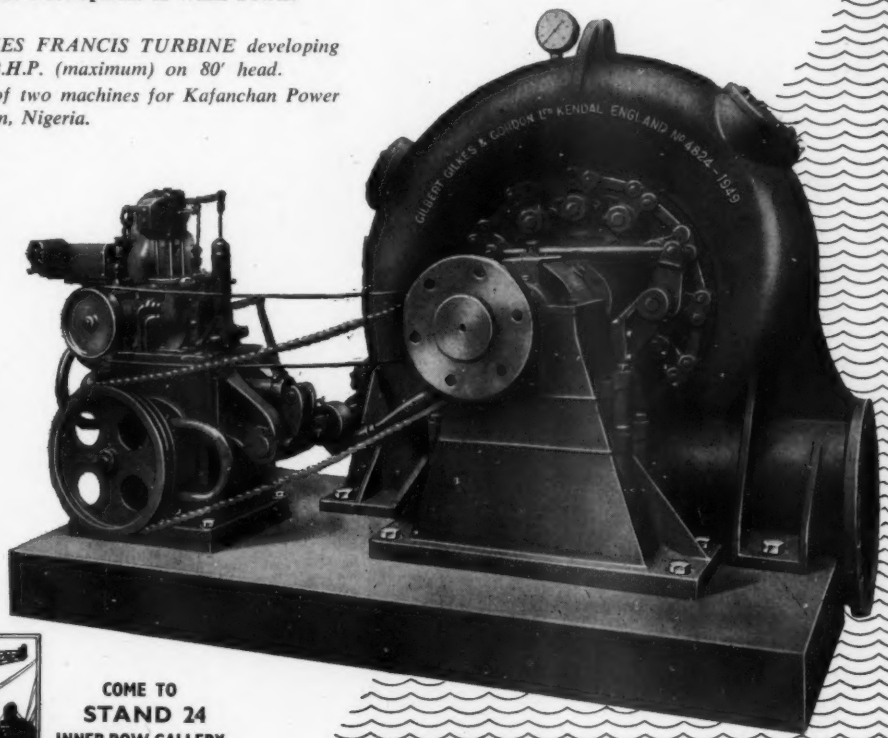
for water power

TYPES OF WATER TURBINE
3.—THE SPIRAL CASED FRANCIS TURBINE

"The spiral form of the turbine casing is designed to give an even flow of water to the guide vanes and runner. This flow is controlled by movable guide vanes operated by an oil pressure governor. The guide operating mechanism consists of a system of links and levers, which is out of contact with the water."

Extract from GILKES handbook—
"On the Development of Water Power."

GILKES FRANCIS TURBINE developing 325 B.H.P. (maximum) on 80′ head. One of two machines for Kafanchan Power Station, Nigeria.



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INNER ROW GALLERY
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AND SEE OUR
WORKING MODEL OF
A HYDRO-ELECTRIC
POWER STATION

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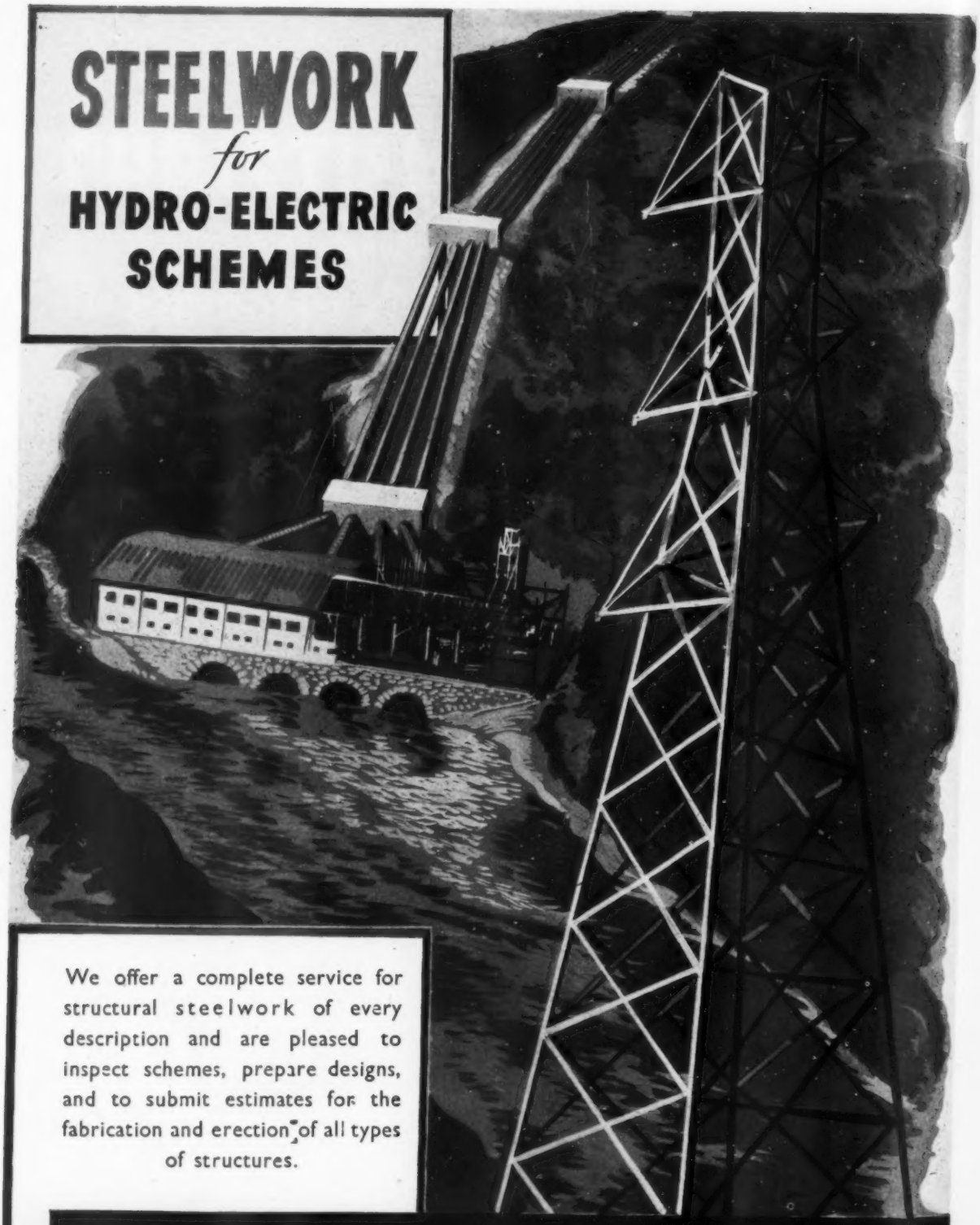
STEELWORK *for* HYDRO-ELECTRIC SCHEMES



We offer a complete service for structural steelwork of every description and are pleased to inspect schemes, prepare designs, and to submit estimates for the fabrication and erection of all types of structures.

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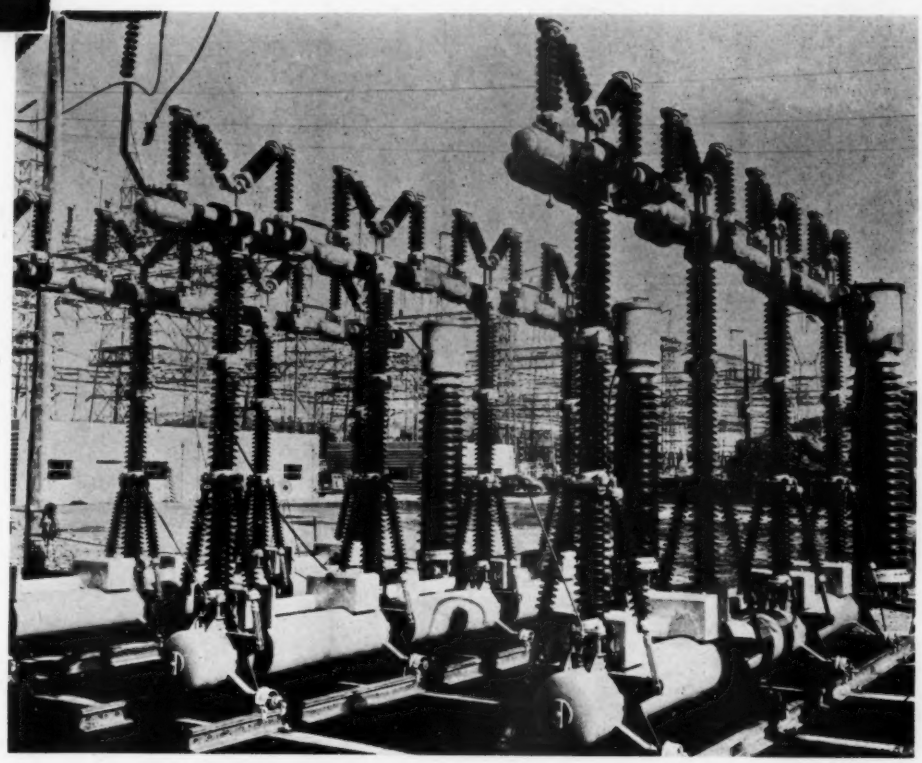
beats all records in America



Brown Boveri air-blast breaker in the large switchyard of the Grand Coulee Dam station in which it was tested by American engineers between the 14th and 18th March, 1951

The tested breaker is an outdoor model for 220 kV and is rated 6 million kVA according to I.E.C. standards or 9 million kVA for American practice. It coped satisfactorily with all the short circuits initiated during the extensive series of tests, which included reclosing operations, and a final test at a much higher power.

The maximum interrupted power was of the order of 41 million kVA (asymmetrical) at a voltage of 238 kV; the breaking time only $^{5}/_{100}$ sec.

After completion of the tests the contacts were removed in a matter of 6 minutes and found to be fully capable of further service.

The excellent properties of our breakers have thus been corroborated under conditions never hitherto encountered in practical service.

To date a total of 565 three-pole air-blast circuit breakers for service voltages of 120-400 kV have been supplied to—or are building for—23 countries; of these, eight, rated 380 kV, 8·5 million kV, were for Sweden.

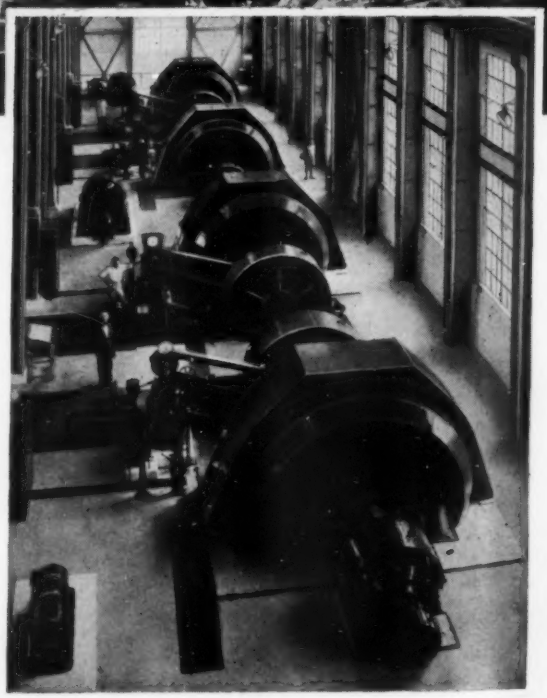
Some other products:

Indoor-Type Air-Blast Circuit-Breakers
Relays for Electrical System Protection
Generators · Transformers · Switchgear · Velox Boilers · Steam Turbines

BROWN, BOVERI & CO.
LIMITED
BADEN (Switzerland)

Hydro-electric Equipment

General view of Shanan Power Station



Four three-phase, waterwheel-driven alternators, (horizontal type, 13,333 kVA., 428 r.p.m., 11,000 volt, 50 cycle) installed in Shanan Power Station for the Punjab Government's Uhl River Hydro-electric Scheme.

For all plant required for
Hydro-electric Power Schemes
Consult BTH.

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THE BRITISH THOMSON-HOUSTON CO. LTD. RUGBY, ENGLAND

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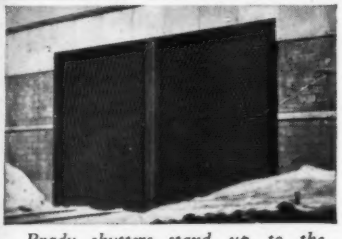
Canada chooses BRADY PATENTED



Brady shutters stand up to the most arduous climatic conditions—this is a Brady installation for Shipping Containers Ltd., in Montreal.

Efficient routine service, no less than enterprise, makes 'Brady' a by-word in Canada too. This gear-operated bank of four steel shutters was recently fitted for the Dominion Textile Company Ltd., of Montreal. A standard roller-shutter installation, it is just one example of everyday service by Brady abroad. There as in Britain, our organisation sets itself out to meet the normal and unusual roller-shutter specifications with equal efficiency.

We shutter the world

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Night and day in all weathers Henderson Aerial Cableways consistently maintain scheduled construction programmes. The speed, economy and efficiency of Henderson Cableways are essential factors in large building, constructional and hydro-electric undertakings. Henderson Cableways were used for the construction of the Dams at Loch Sloy and Glen Shira, North Scotland, Hydro-Electric Board, and various other home and overseas undertakings.

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We have built Hydraulic Turbines with a total capacity of over 15,400,000 H.P. including Impulse Turbines aggregating over 3,600,000 H.P.

J. M. Voith, G.m.b.H., Engineering Works
Heidenheim (Brenz), Germany

North of Scotland Hydro-electric Scheme

The supply and erection of some ninety miles of 132kV overhead transmission lines, over the wild and rugged Highlands, was recently entrusted to Henley's Contract Department by the North of Scotland Hydro-Electric Board.

Illustration. Hillside view of HENLEY 132kV single circuit towers overlooking Loch Luichart. (Note: The footings of one tower are above the peak of the other which is only 150 ft. distant.)

Consultants: Messrs. Kennedy and Donkin

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ELECTRIC CABLE
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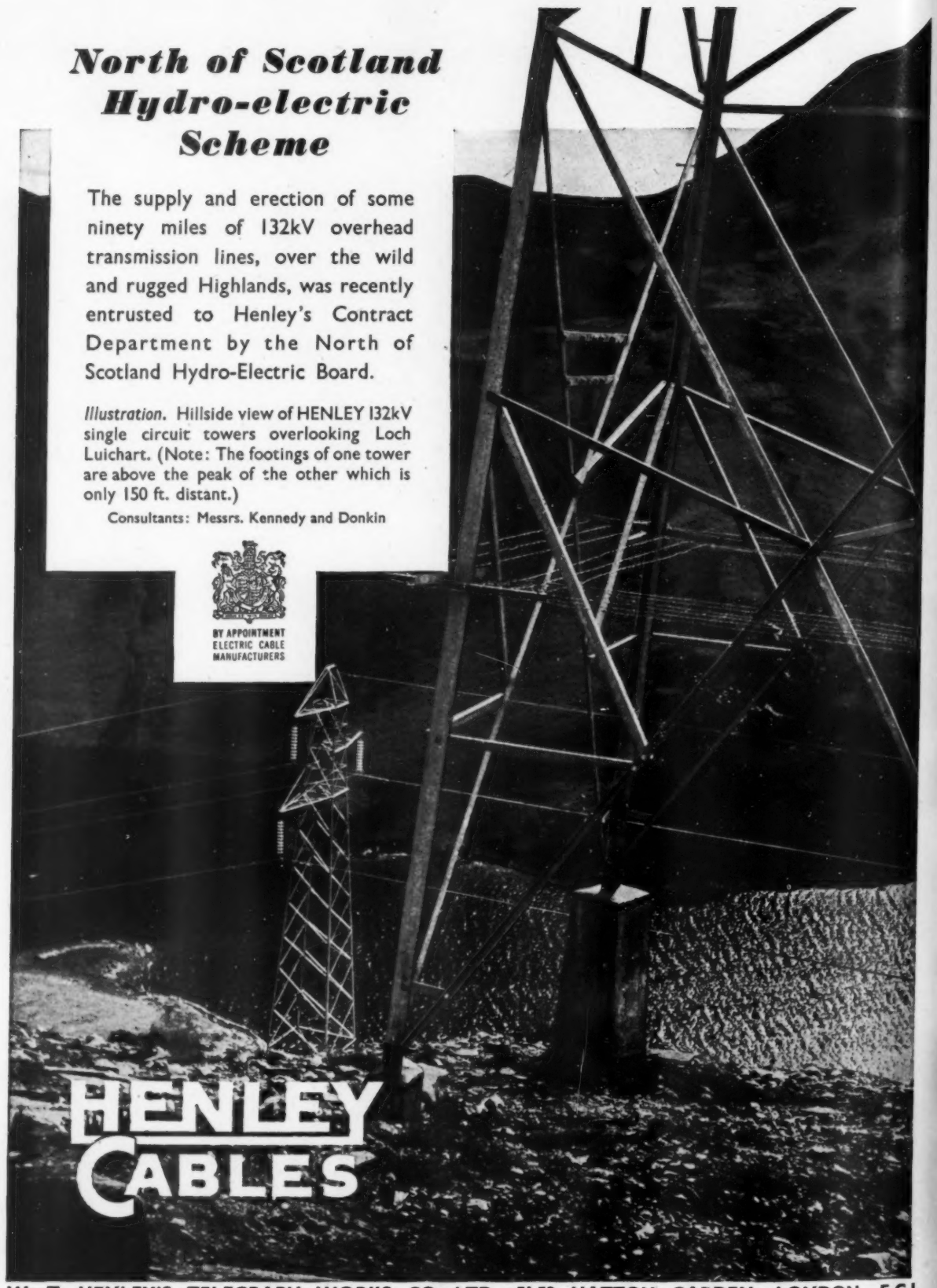

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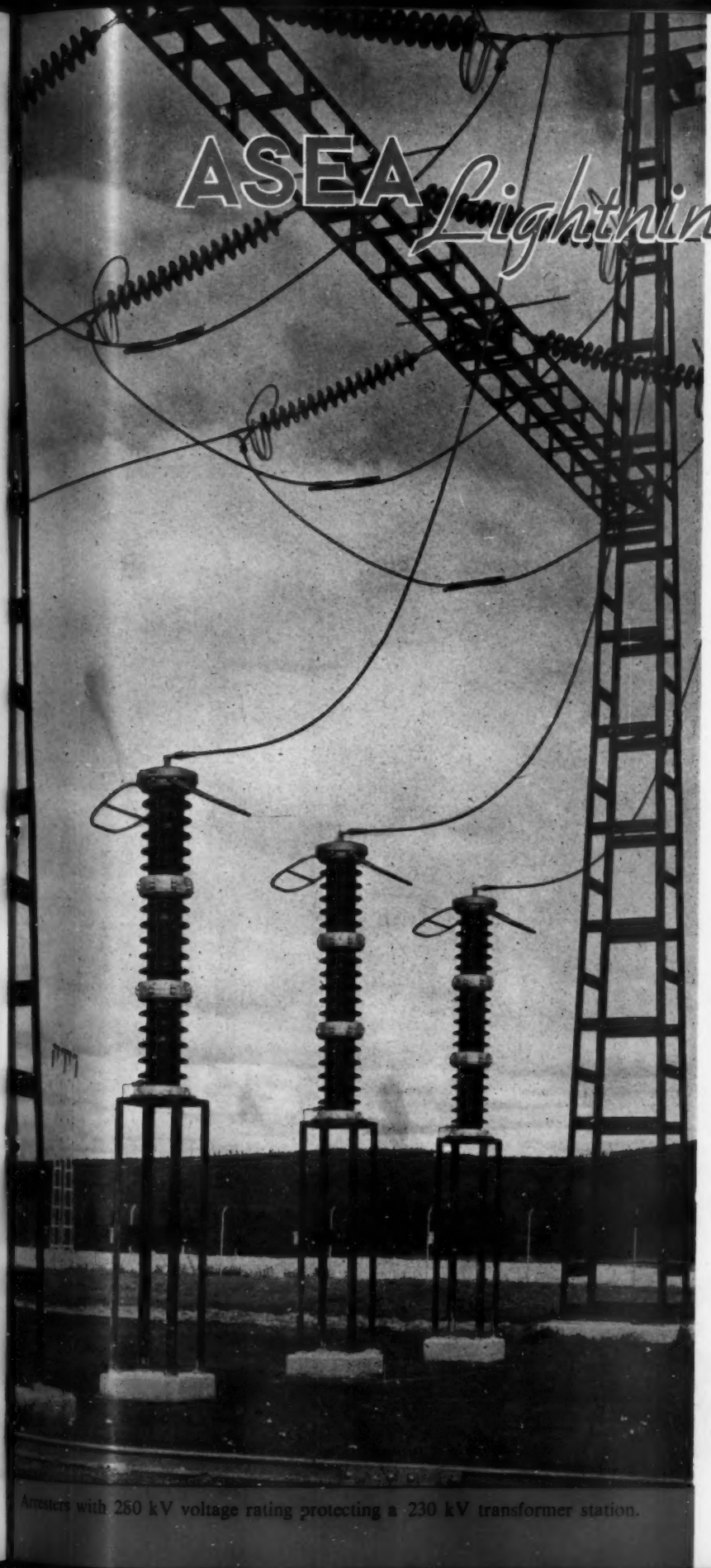


Arresters with 260 kV voltage rating protecting a 230 kV transformer station.

ASEA *Lightning Arresters*

—unrivalled for plant protection and service reliability

Outstanding features:

Low spark-over level at high impulse steepness

Low discharge voltage

Precision in manufacture: discharge voltage guaranteed to ± 5 per cent.

Perfect sealing

Built as a self-supporting column up to the highest ratings, with consequent low installation costs

★

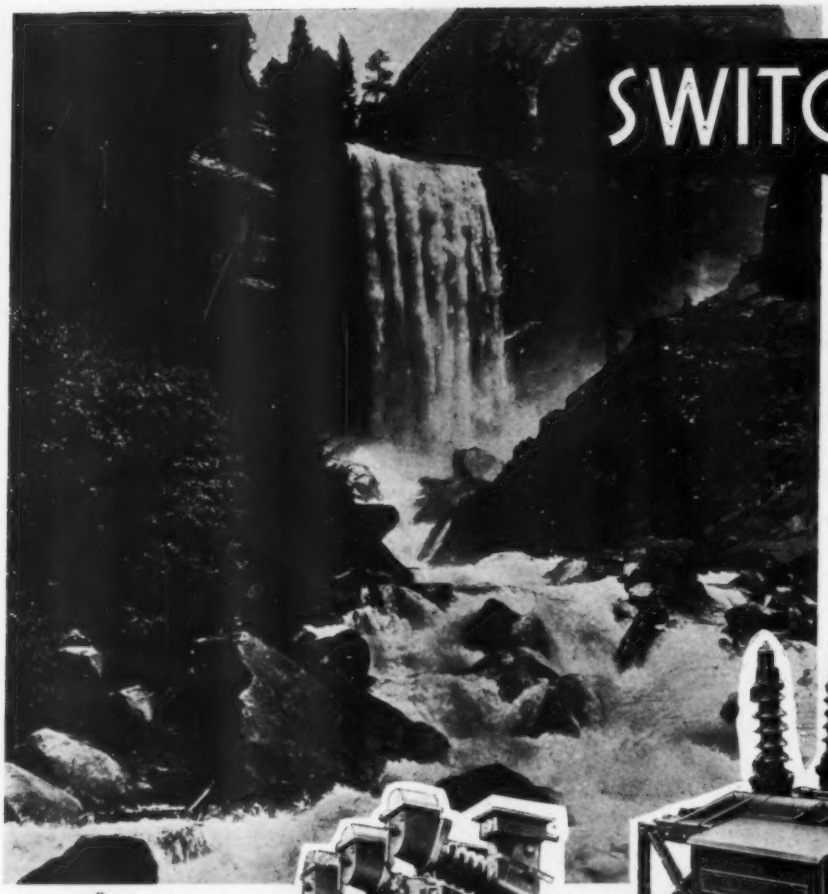
The arresters are manufactured in three different series according to their current rating: a heavy duty and a standard series tested according to the American Standards AIEE 28 A 1950 for Station Arresters (10 000 A) and a light series tested according to the same Standards for Line and Distribution Arresters (5000 A).

Standard Arresters for voltage ratings of 160 kV and below are held in stock. Short delivery time for larger arresters.

Write for pamphlet 7229 Ea.

ASEA

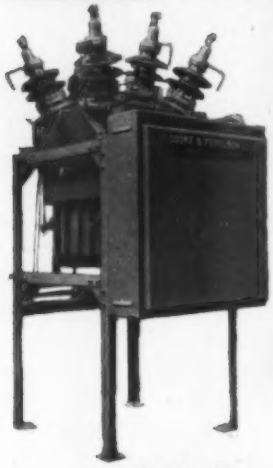
Västerås - Sweden



SWITCHGEAR

for HYDRO ELECTRIC SCHEMES

Three examples from the C and F range of Outdoor Oil Circuit Breakers are illustrated below. The complete range extends from 2,000 volts to 138 kV for both indoor and outdoor service under the most arduous conditions.



TYPE OE5
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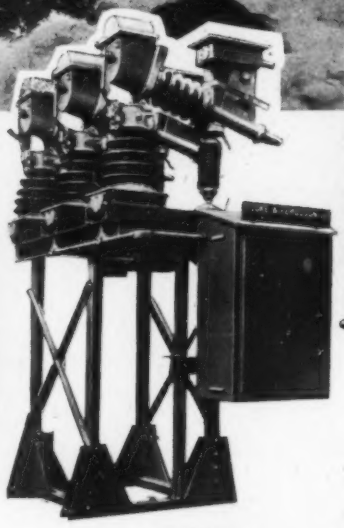

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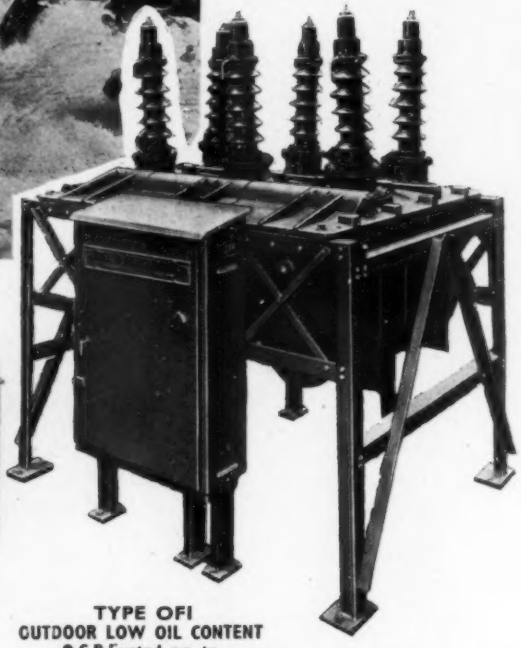

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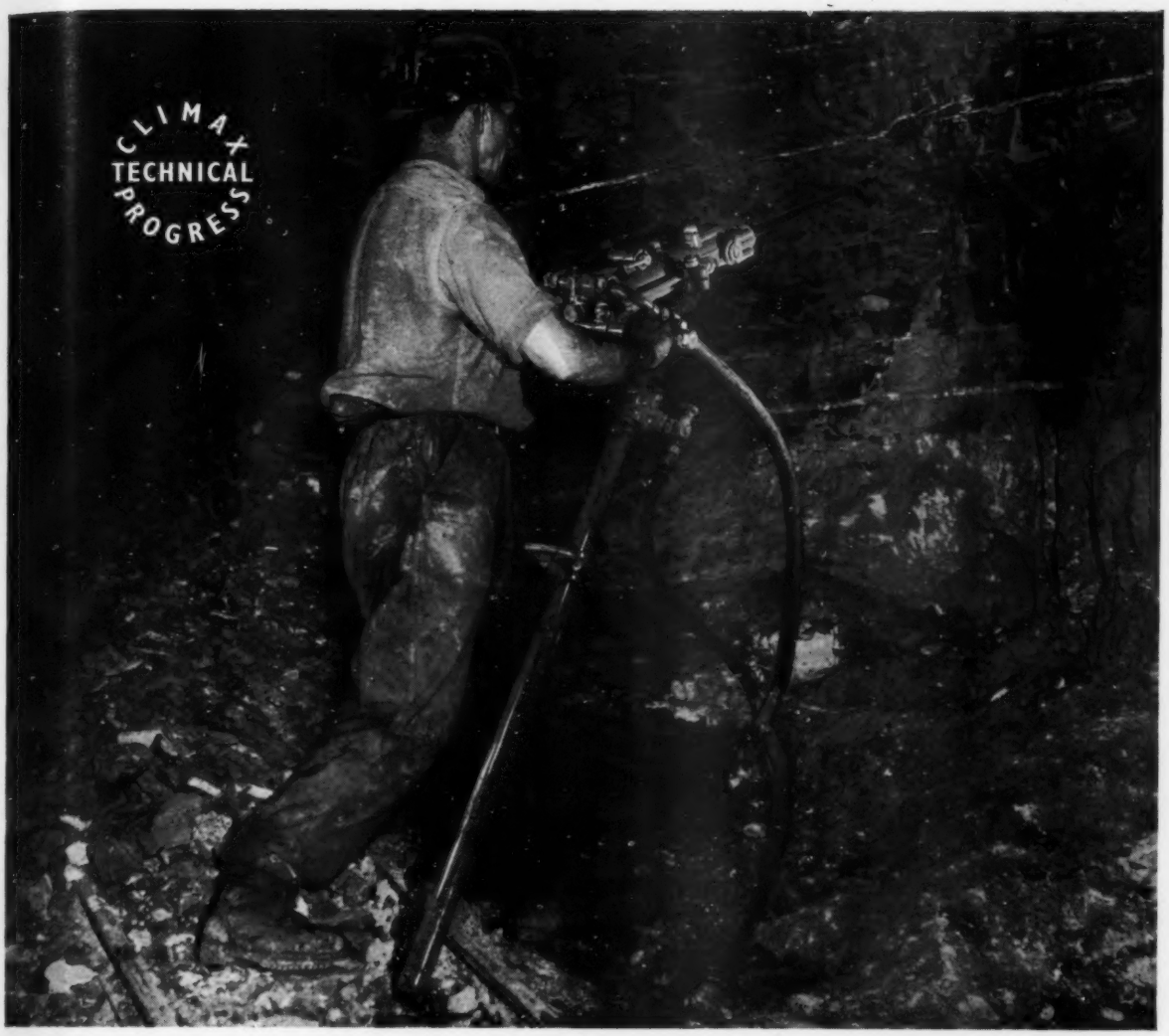

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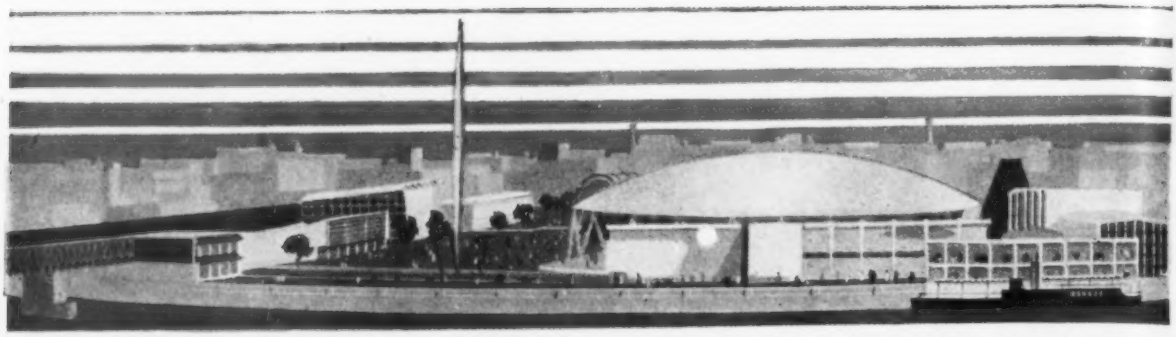

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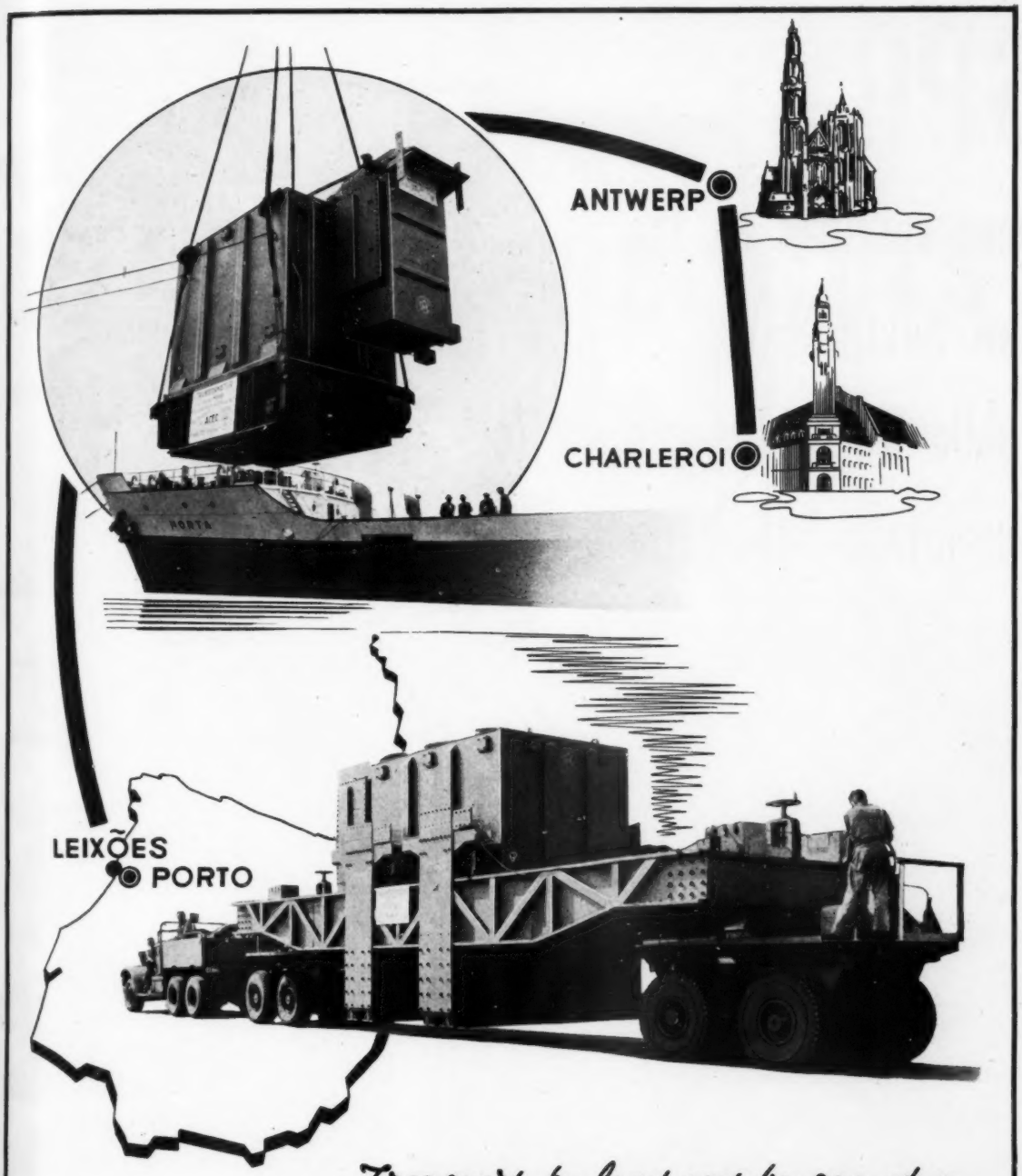

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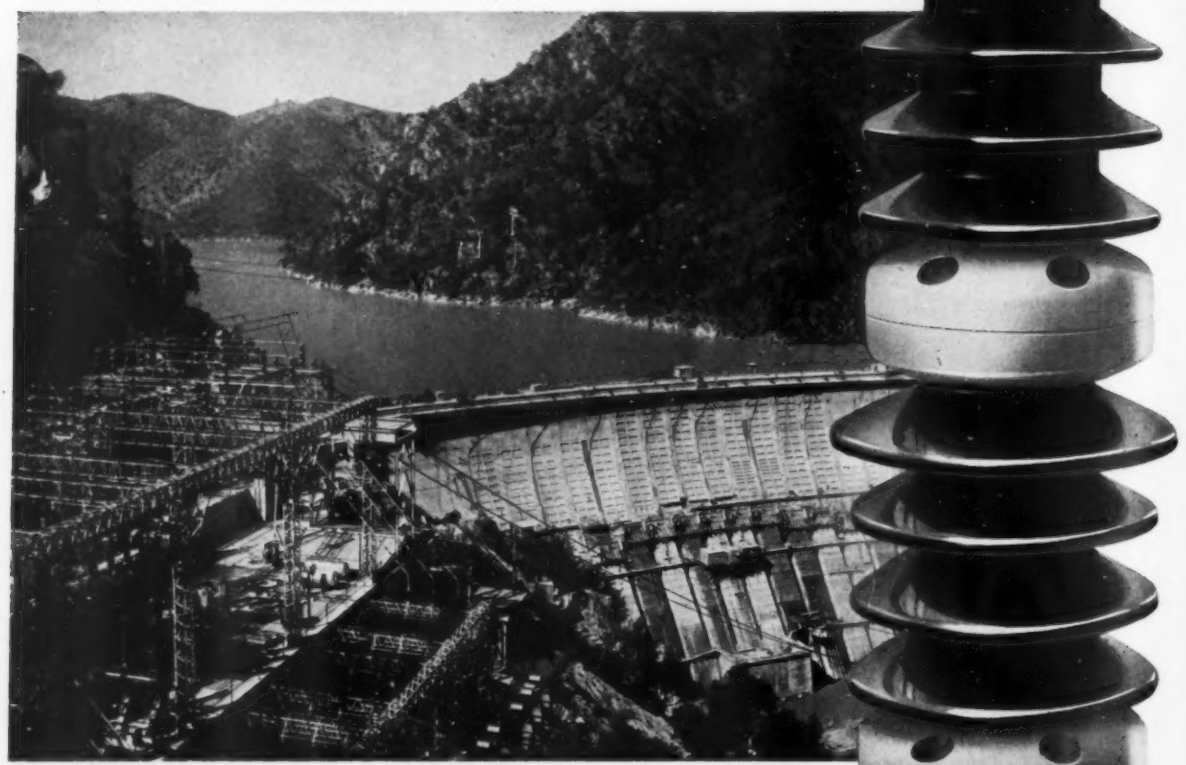

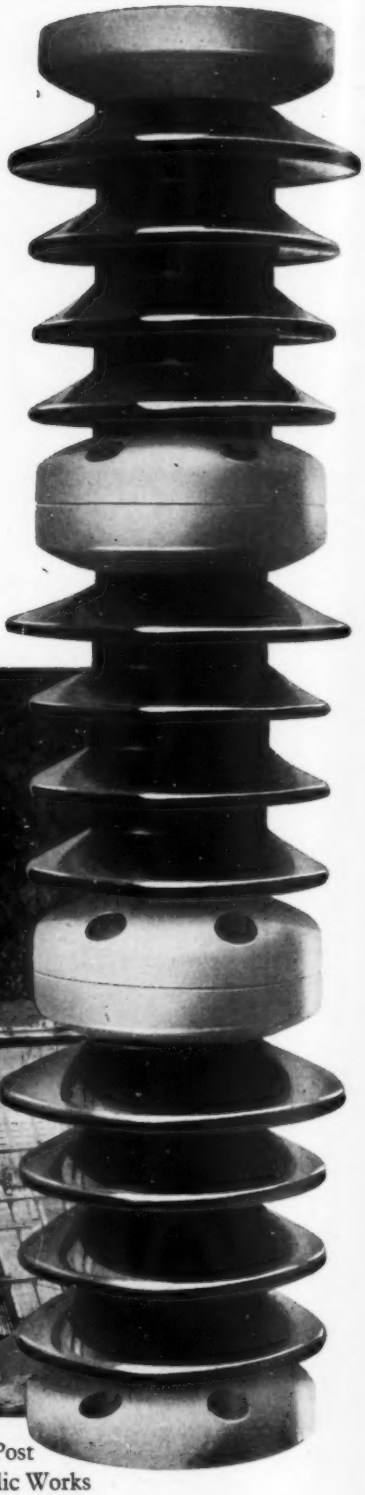

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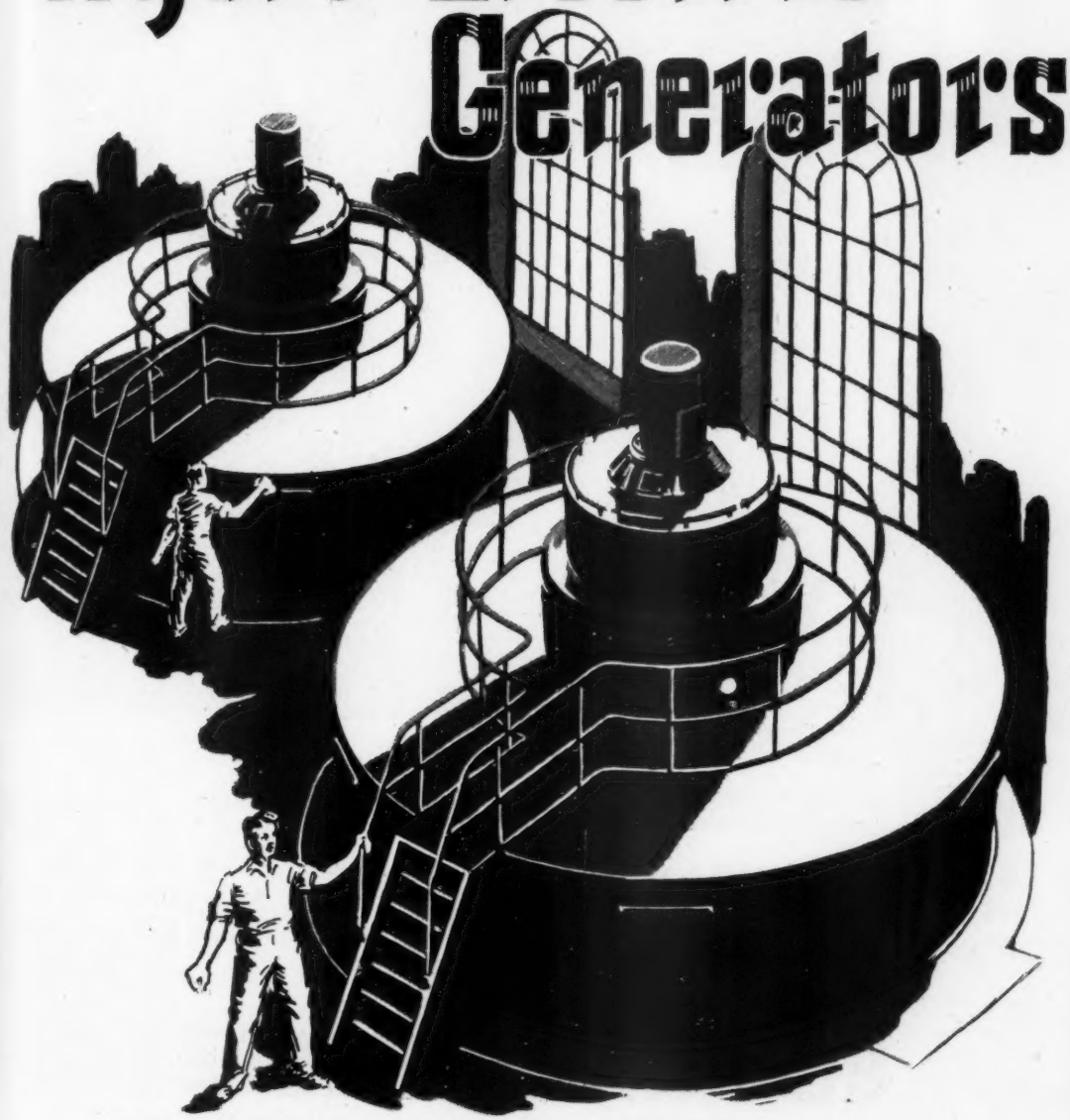

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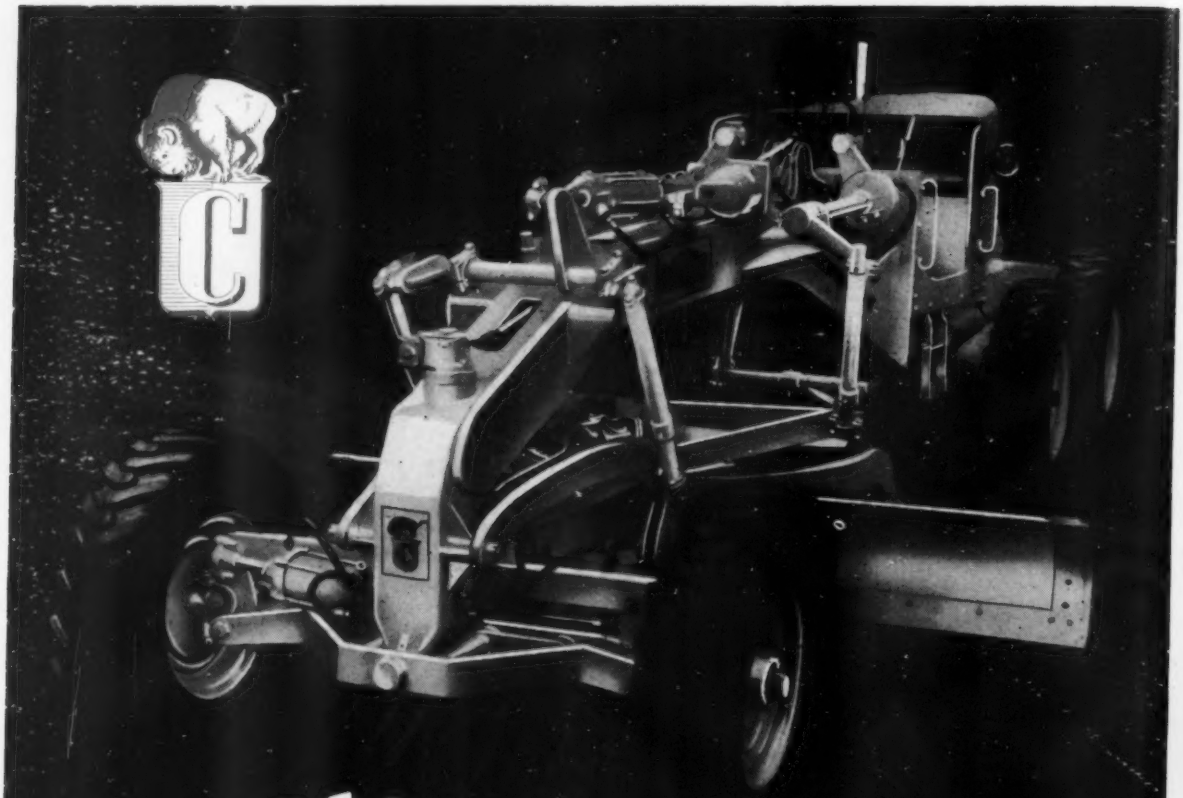

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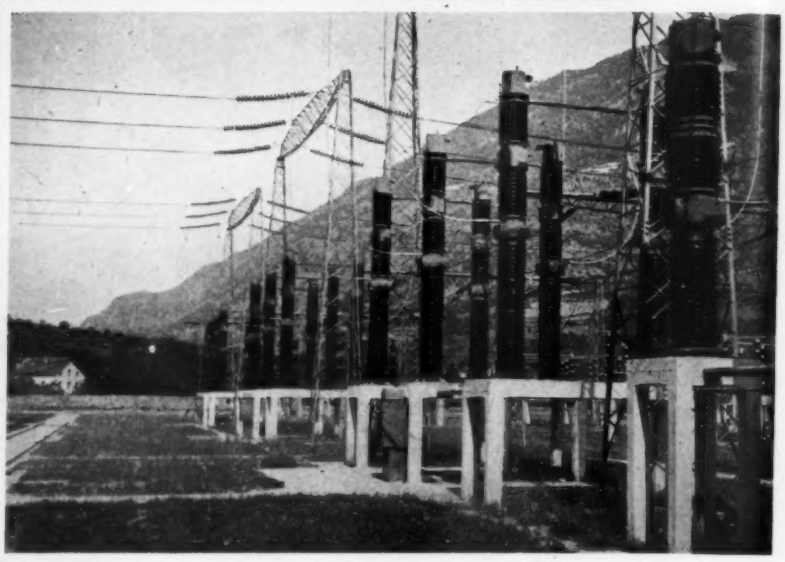

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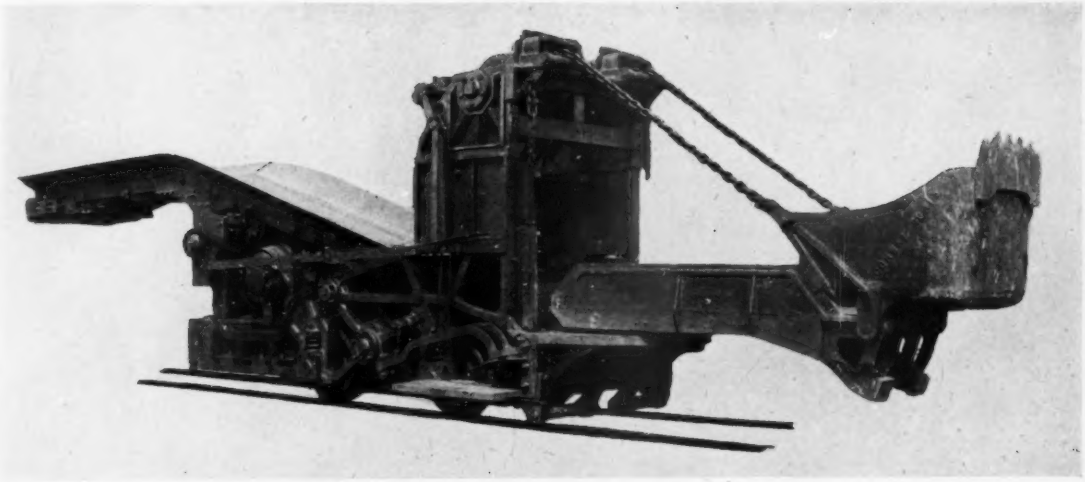

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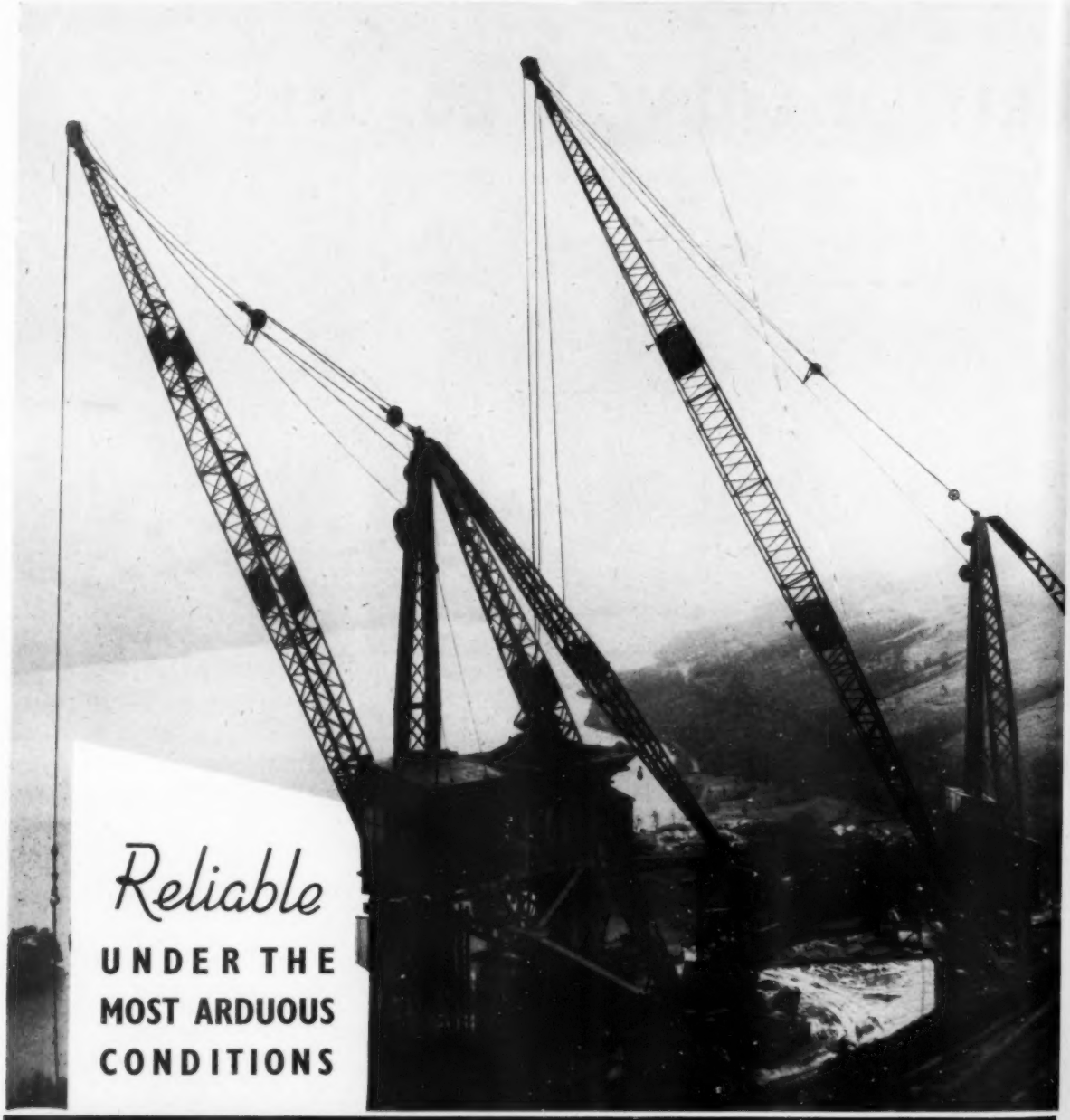

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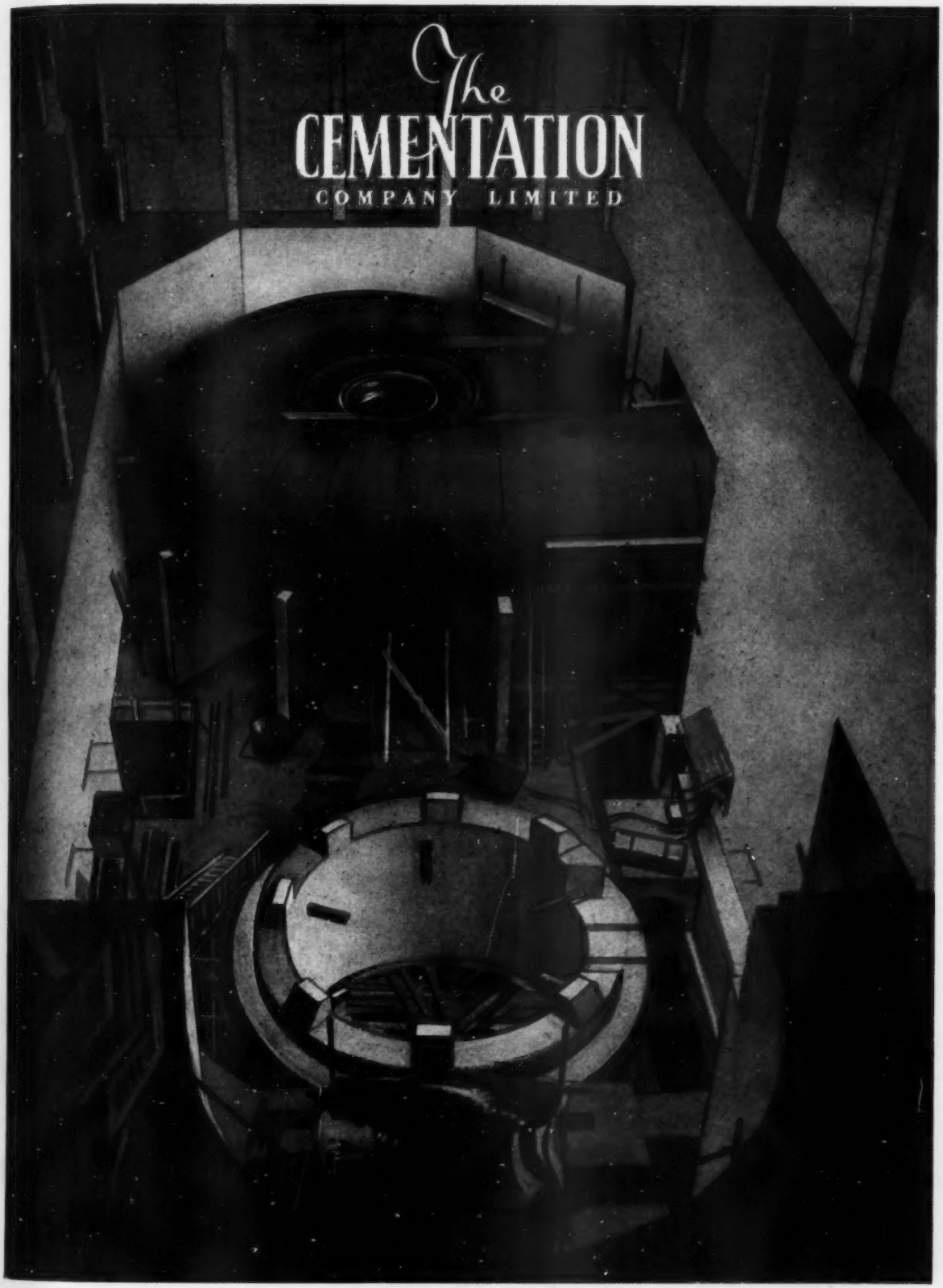

Cathleen Falls Power Station under construction

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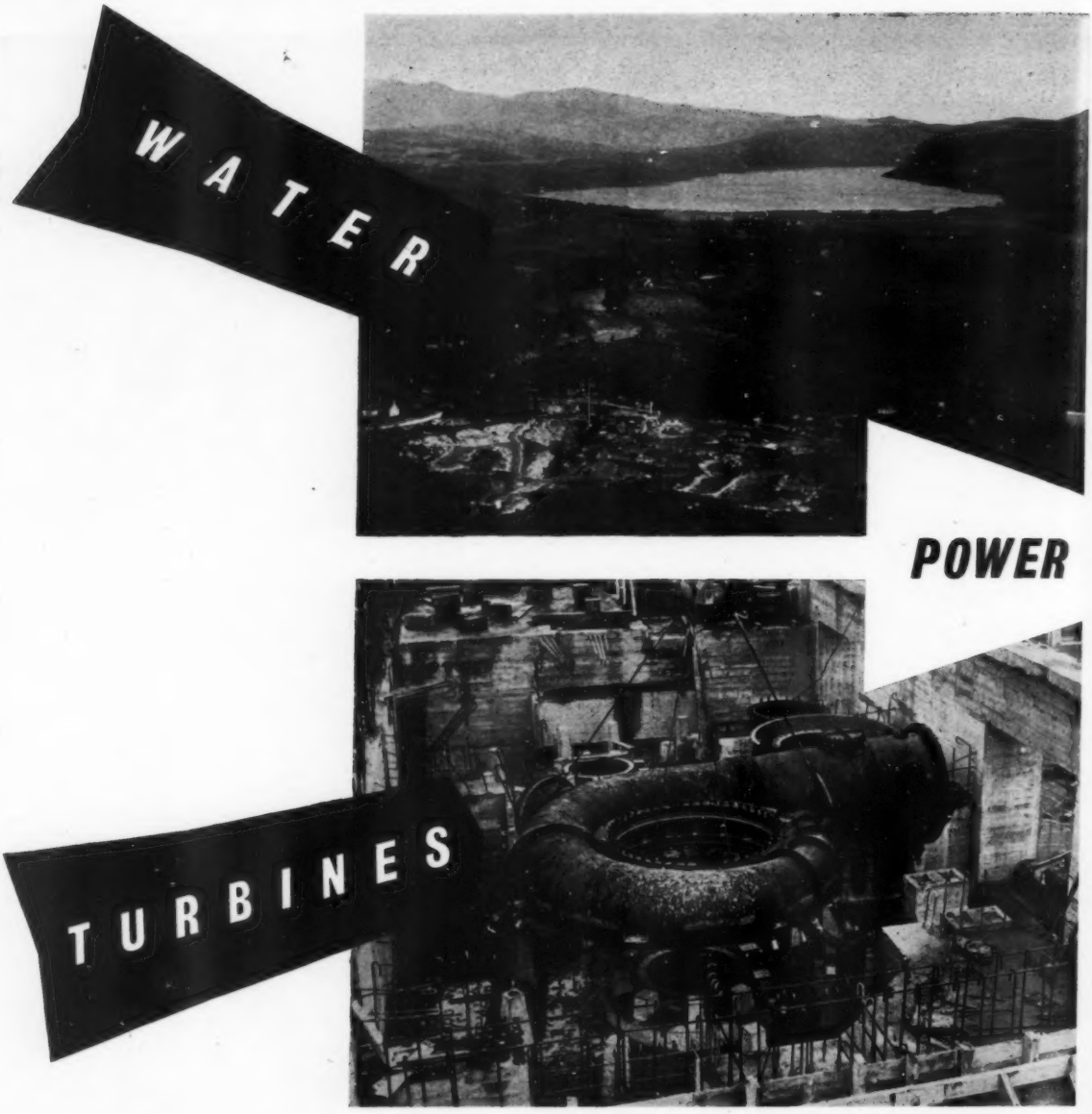

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Re-Powering Europe

FROM time to time the constantly changing economic condition of the western part of the European continent is brought into the limelight of public interest by political or quasi-political discussions and controversies, usually with indeterminate results. Yet on one important point there is fairly general agreement, and that is the overriding need for co-operative effort in many forms by many countries in facing a situation that bears every evidence of becoming more acute than ever since the close of the war. The significance of the Schuman Plan for Europe is that no single nation subscribing to it is to-day capable of supporting itself adequately out of its own resources. That Britain chose to stay outside the scope of the original scheme was due, of course, to her important Commonwealth and colonial associations and commitments. None the less there are aspects of this admittedly difficult situation in which Britain's world-wide interests could actually be a factor calling for her closer association with Europe, and most certainly an essential element to Europe's political independence. For this reason alone it is to be hoped the parliaments of the British Commonwealth, now that they have been invited to send observers to the Strasbourg conferences, will later have their permanent representatives attending the meetings of the Council of Europe.

Whatever the future of Europe may be, power supplies must constitute a cardinal feature of her recovery programme. Recognition of this is to be found in the comprehensive survey on European engineering published a few weeks ago by the United Nations Economic Commission for Europe. From time to time this journal has described in detail many of the hydro-electric schemes either under construction or in contemplation. In the pre-war period Europe was the world's leader in power production and transmission equipment, and could not only meet its own needs but also contribute substantially to the requirements of other countries by reason of its continuously improving techniques. Much of the modern equipment developed in the United States was, in fact, of European origin. But war's devastation and the colossal demands of reconstruction have brought a tremendous increase in the need for electric power and, as we have seen in Great Britain, and still more in continental countries, has imposed a severe strain on the production capacity of the industry. Yet, we are assured by the highest authorities, it is still potentially capable of meeting Europe's needs, and additionally making a large contribution to the solution of Europe's balance of payments problem.

The desirable effect of this objective of greater production in types of electric power equipment now so difficult to obtain is shown in the report we have quoted. For one thing it would mean an increase in the outlets for other equipment of which there is to-day apparently a surplus. "This," the committee stresses, "would not only facilitate the completion of Europe's own power development programme, but would also increase supplies available for export overseas. Under-developed countries, in particular, need greatly increased quantities of electric power. Power development schemes tend to be given priority in the allocation of finance, but the scarcity of equipment is a real problem." Then, summing up this most important aspect of Europe's engineering industry, the report strikes a note of definite, if qualified optimism regarding the future. "Even apart from the high level of Europe's own demand," it comments, "the outlet for this section of the engineering industry in the world's markets for many years to come appears to be most favourable, and to warrant expansion of productive capacity to a greater extent than at present envisaged." Incidentally, it is pointed out that, except in the case of water turbines, between 25 and 40 per cent. of European electrical equipment production is accounted for by the United Kingdom.

It is the financial side of this and similar problems confronting free Europe that is bedevilling every one of its governments to-day. But this problem, like others, will have to be resolved by wholehearted co-

operation unless Europe is to become another group of backward nations, and there is plenty of ground for believing such a retrograde step will not take place. In fact, it was precisely for such a situation as we have briefly outlined here that the International Bank for Reconstruction and Development was created almost seven years ago at the Bretton Woods conference in the United States. So far the bank has made loan commitments totalling over 830 million dollars, and production has been financed in 15 countries, the borrowers using the money for goods and services essential to rehabilitation or development of their productive capacity. Of the loans officially listed by the bank 14 have been for purposes connected with electric power development, but the majority of these examples have been outside Europe.

It is important to remember, when considering the position in Europe to-day, that one of the principal activities of the "World Bank," as it is popularly termed, is to make and guarantee loans for projects of reconstruction or development in the territories of its members where private capital is not available on reasonable terms. Mr. Eugene Black, the Bank's president, spoke in this sense when he addressed himself to financial journalists of many countries at the recent flotation of the first issue of World Bank stock in London — the first, in fact, to be issued in any country outside the United States. True, the offer was fairly small, and the President emphasised at the time that it was all that was required to meet immediate needs. Nevertheless the long term objective is to create markets in Europe for the bank's securities. Conversely nowhere is the need for assistance in reconstruction more urgent than in Europe, or the prospects better provided that assistance is freely available.

Australia Forges Ahead

AUSTRALIA, according to latest reports, is planning in virtually every direction for great industrial expansion in the next 20 years. The enormous increase in power supplies which will accrue from the Snowy Mountains and other hydro-electric schemes is bound to have repercussions on all manner of industrial activity. Educational institutions too are keeping pace with the general advance. The New South Wales University of Technology, for example, has decided to increase its teaching staff in the faculties of engineering, science and architecture. The former courses for university degrees and technical college diplomas have been merged, and enrolments have increased from 250 last year to more than 3,000 this year, indicating the optimism with which the future is regarded by those responsible for educating youth. The university's activities extend northwards to Newcastle, south to Wollongong, and west to Broken Hill.

Pipe Friction Losses

IN the annual report, which has just been published, of the British Hydromechanics Research Association, there is a survey of active research work. Referring to pipe friction problems it states that the estimation of friction losses is of considerable economic importance not only because of its direct bearing on the cost of the pipeline itself, but also because an inaccurate estimate may result in the pumps, turbines, or other components of the system operating off their designed duty point with a disproportionately large loss of efficiency.

The friction coefficient varies in a complex way both with the Reynolds Number (that is, with the diameter of the pipe and the velocity and kinematic viscosity of the fluid) and the so-called relative roughness of the pipe walls, the effect of which is not constant. Owing to this complexity there are numerous formulae in current use, some of which give widely differing predictions.

The Association has made an extensive survey of existing information with the object of evolving formulae which will best represent actual conditions. It is hoped to make recommendations shortly with regard to new commercial water pipes, after which consideration will be given to the more general case of the flow of other fluids and of the effect of the age of pipes on their hydraulic roughness. Facilities for experimental work will be provided in the new laboratories and some full scale field tests will also be carried out.

Colombo Plan Finance

THE Colombo Plan for the development of south-east Asia is the subject of cautious comment by Professor Raymond Firth writing in the Westminster Bank Review. In particular he deals with the financial aspect of the plan, remarking that even if the financial side is fully implemented the results from some points of view will be on a modest scale. It could not represent any spectacular raising of standards of living of the great mass of populations. Should the full financial support required not be forthcoming, Professor Firth goes on, the result may be only to hold the existing standards level in face of a rapidly increasing population. "The plan," he sums up, "is perhaps over-optimistic in suggesting that the expansion of the population may be only short term, and that a general improvement in living standards by itself will tend to reduce the rate of increase."

Water Resources of Canada

THE Water Resources Division, Engineering and Water Resources Branch of the Department of Resources and Development, announces the publication of Volumes 102 and 104 of the Water Resources Papers dealing with the surface water supply of Canada.

No. 102 refers to the Province of British Columbia and in Yukon Territory. The organisation and the scope of the investigating work is briefly outlined and the report contains 418 pages of stream-flow data for rivers and streams in the Pacific Drainage Division, including mean temperature and precipitation records at a number of locations in the area.

The second paper (No. 104) contains the results of the hydrometric investigations carried out by the Water Resources Division in the Provinces of New Brunswick and Nova Scotia. A short explanation of the organisation and scope of the work is given and the report contains 53 pages of stream-flow data for rivers and streams in the Atlantic Drainage Division (south of the St. Lawrence River), including precipitation records at a number of locations in the Maritime Provinces. These reports may be obtained upon

application to the Chief, Water Resources Division, Department of Resources and Development, Ottawa. The price of No. 102 is $1.00 and of No. 104, 50 cents; remittances accompanying an order should be in favour of the Receiver General of Canada.

The Severn Barrage

IN the House of Commons on June 4 the Minister of Fuel and Power was asked whether he was now able to make a report upon the investigations that had been taking place on behalf of his Department concerning the proposal for the utilisation of the tidal power of the River Severn for the production of electric current. Mr. Noel Baker said that experiments with a tidal model were essential before it was possible to proceed further with the investigation of the project for a Severn Barrage. It was hoped that this model would be completed in 1953 or early 1954.

Glen Shira Tunnel Thirled

THE last plug of rock in the four and a half mile long main tunnel of the North of Scotland Hydro-Electric Board's Glen Shira Scheme, which when completed will have an output of 80 million kWh, was blown through on June 1. The 10 foot diameter tunnel, on which work started in November, 1949, will lead water from the lower dam of the scheme to the power station now under construction at Clachan.

The tunnel was driven mainly from six independent faces with a maximum of ten squads of eight men working simultaneously. During the driving the British tunnel driving record was broken on two occasions. In November last year 245 feet were driven in one face by two squads working 12 hour shifts over seven days. In January 1951 this record was broken when a drive of 247 feet was achieved. A total of more than 85,000 cubic yards of rock had to be excavated to complete the tunnel.

An unusual feature of this tunnel is the inclined pressure shaft, 2,060 feet in length which is the first of its kind in Britain. The shaft, which descends at the rate of 1 in 1¼, was one of the first sections of the tunnel to be started.

Mr. Thomas Johnston, Chairman of the North of Scotland Hydro-Electric Board, gave a brief outline of progress by the Board at the official opening of the £250,000 diesel generating station at Kirkwall, capital of the Orkney Islands. He also disclosed that from the vesting date, April 1, 1948, the Board had connected up 55,000 new consumers, equal possibly to something like 175,000 people. "We have therefore linked up nearly one third of the potential consumers in our area, which constitutes a remarkable and praiseworthy record," he said.

S. Rhodesia's Progress

ONE of the greatest advantages of Gwelo, one of the most rapidly developing townships of Southern Rhodesia, is its abundant water supply, according to official sources, and this is now being developed in many directions for the service of industry. The Ngamo Dam, with a capacity of 340 million gallons, was clearly not sufficient if industry was to be attracted to the town in greater volume, so a search was made for another dam and Whitewaters was built with a capacity of 1,150 million gallons. These two dams alone will ensure that the town has sufficient water for two years, but a survey for a third dam is at present going forward. At present electrical power to factories in the heavy industrial field is supplied by the municipality, but power for Rhodesian Alloys Limited, which has chosen the town as a centre for the processing of ferro-chrome, will come from a new Electricity Supply Commission station to be erected on a 30 acre site.

Kariba Gorge Plans

IT is likely to be several weeks, according to news from reliable sources, before the report of the Inter-Territorial Hydro-Electric Power Commission on the Kariba-Kafue scheme becomes generally available. This, of course, is a matter for the governments concerned, and it will probably be well on into the summer before there is any general release. The engineers' report was made purely to the Commission some time ago, and is confined to those technical aspects of the project which the Commission specially referred to them. The general terms of reference to the Commission, however, were much wider in scope, and doubtless the report ultimately will be presented to the Central African Council, since, as the Chairman of the Commission (Mr. A. B. Cowan) has stated, the plan is not only for Southern Rhodesia, but really for Central Africa as a whole.

Aluminium for Transformers

THE Canadian Electric Company has received an order for sixteen 20,000 kVA oil-cooled transformers for the Chute de Diable power station on the Peribonka River. One bank of three transformers will have windings of aluminium wire instead of the conventional copper. This is probably the first application of its kind.

Fuluasou Hydro-Electric Scheme

THE hydro-electric scheme on the Fuluasou river, in Apia, Somoa, was engineered by the Department of Island Territories in Wellington, New Zealand, under whose jurisdiction these islands are governed. The scheme comprises a single unit, and the prime mover is a twin "Turgo" water turbine constructed by Gilbert Gilkes and Gordon Limited, of Kendal, Westmorland, and is coupled to a 287 kVA B.T.H. alternator, generating at 400 V 3-phase 50 c/s.

The reservoir stores 1,400,000 cubic feet of water, and from the dam a pipeline, comprising 8,245 feet of steel pipe, 3/16 in. in thickness, runs to the power house, giving an effective static head at the turbine of 206 feet. The pipeline was solidly welded, using slip-type joints with an average lap of 1⅛ in., and the erection welds consisted of a run of No. 10, followed by a run of No. 8. Twenty-four expansion joints are fitted in the run, and during welding the maximum expansion at any joint was 1¾ in. This was due to the combined action of sun temperature reaching 94°F., and the build up due to absorption of heat from the welding process which combined to give an inside pipe temperature of 153°.

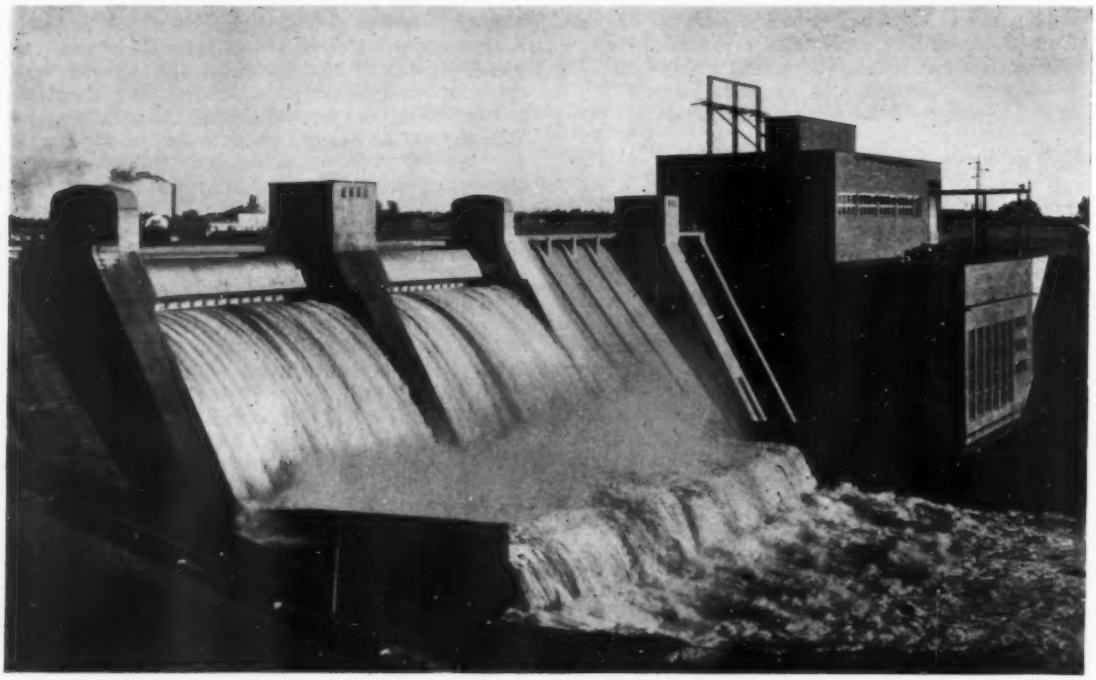


Fig. 1. Harjavalta Power Station, 75,000 kW capacity, on the River Kokemäki

Power Resources of Finland

In this article Mr. Bror Nordqvist discusses the power resources of Finland, emphasising the difficulties that have been created by the war and explaining the necessity to develop the potentialities that exist in the northern part of the country.

IN Finland the production of electrical energy as an industry in a proper sense was entered upon at a comparatively late date—in 1920 or thereabouts—but developments since then have been very lively indeed. From a very modest beginning of 200 million kWh per annum in 1918, the production increased to 3,100 million kWh in 1938, the last year before the war, that is, 15-fold. During the corresponding period the consumption of electrical energy in Sweden did not increase more than three times, but, of course, our production in 1918 was very modest indeed, amounting to a few per cent. only of that in Sweden. In 1938 the corresponding figure was 38 per cent. The same period also shows an unprecedented economical and industrial expansion in Finland.

The abnormal conditions following the outbreak of the second world war, however, brought about an interruption in this development. The industrial energy consumption decreased very considerably due to reduced export facilities. An exceptional drought period between the autumn of 1939 and the spring of 1943 and a second low water period 1946-1948 had a similar effect on power production. A third cause of decline is due to the territorial losses sustained as a result of the war.

The total energy consumption of Finland, which in 1939 was about 3,100 million kWh, went down in 1940 to 1,700 million kWh; it then gradually increased until it practically reached the pre-war value, remaining practically constant during the period 1945-1948 at a value slightly below 3,000 million kWh per annum. In 1949 and 1950 the power supply again improved owing to new power plants coming into operation. The energy production amounted to about 3,555 and 4,200 million kWh respectively. In 1948 relative consumption dropped to 20 per cent. of that for Sweden, where it has been possible to follow a normal course of development. In 1950 this proportion again increased to 23 per cent.

TABLE I

ENERGY PRODUCTION IN FINLAND AND SWEDEN

Year	1938	1948	1950
Sweden, millions of kWh per annum	8150	14300	18300
Finland, millions of kWh per annum	3108	2960	4200
Finland, as a percentage of Sweden	38	20	

The population of Sweden amounts to 6·8 million and that of Finland to about 4·0 million people approximately. Table II throws some light upon the

proportionate energy consumption in Finland for different purposes at present and in 1939.

TABLE II

DISTRIBUTION OF THE ENERGY CONSUMPTION IN FINLAND

Consumers	1939	1949
(1) Woodworking industries -	56·5%	49·0%
(2) Other industries excluding (3)	11·5%	12·8%
(3) Electro-chemical and thermal industries - -	9·8%	10·0%
(4) Electric boilers - - -	12·0%	11·3%
(5) Civil and public requirements - - - -	8·0%	14·7%
(6) Own consumption of the power plants - - -	2·2%	2·2%
Total -	100·0%	100·0%

The energy supply in Finland is chiefly based on the utilisation of the water-power resources. To some extent back-pressure steam-power plants have been able to compete economically with the water power, but only where process heat is required. In 1938 about 80 per cent. of the power consumed was generated in hydro-electric power plants, 15 per cent. in the industrial back-pressure steam-power plants and 5 per cent. by means of condensing steam turbines.

In 1947 about 67 per cent. of the energy demand was generated by water power, 13 per cent. by back pressure and 20 per cent. by condensing steam-turbines. In 1948 the corresponding figures were 65, 14 and 21 per cent. The share of the condensing steam plant was thus considerably increased in 1947 and 1948. As fuel prices in general have been comparatively high after the war, the shortage of water power has indeed been a serious encumbrance to industrial production. In consequence, in 1947 and 1948 it was necessary to resort to rationing in order to keep, as far as possible, the vital industries supplied with energy. In 1950 the conditions were again getting normal due to the new water-power plants. The share of the water power amounted to 88 per cent., 8 per cent. of the demand being generated by back pressure and 4 per cent. by condensing steam turbines.

At the outbreak of the second world war the amount of water power produced in Finland amounted to approximately 3,000 million kWh and projects were either in course of construction or in the state of final planning to produce an additional 2,000 million kWh per annum, making a total of 5,000 million kWh with a normal flow of water. After the war, hydro-electric plants represented, at normal flow, an annual energy production of 2,500 million kWh, the corresponding installed generator capacity being about 415 MW; but due to the exceptional low water the production in 1947 and 1948, production went down to about 1,900 millions of kWh. Thanks to the heavy importation of coal and oil, and with all the steam-power plants of the country working at top load, an additional 1,000 million kWh of steam power was generated, resulting in a total annual energy production of about 2,900 million kWh.

Hydro-electric projects now in the course of construction includes in all eleven power plants and one extension (see Table IV), begun successively in the years 1940-1946. The contractors have worked under very difficult conditions during this period. During the war, there was a considerable shortage of workers and materials. Foreign currency was very scarce, and affected the placing of absolutely necessary orders abroad until quite recently and the financing of these works has been a severe handicap. The civil engineering work, however, is largely completed, and in some cases power stations have been waiting some years

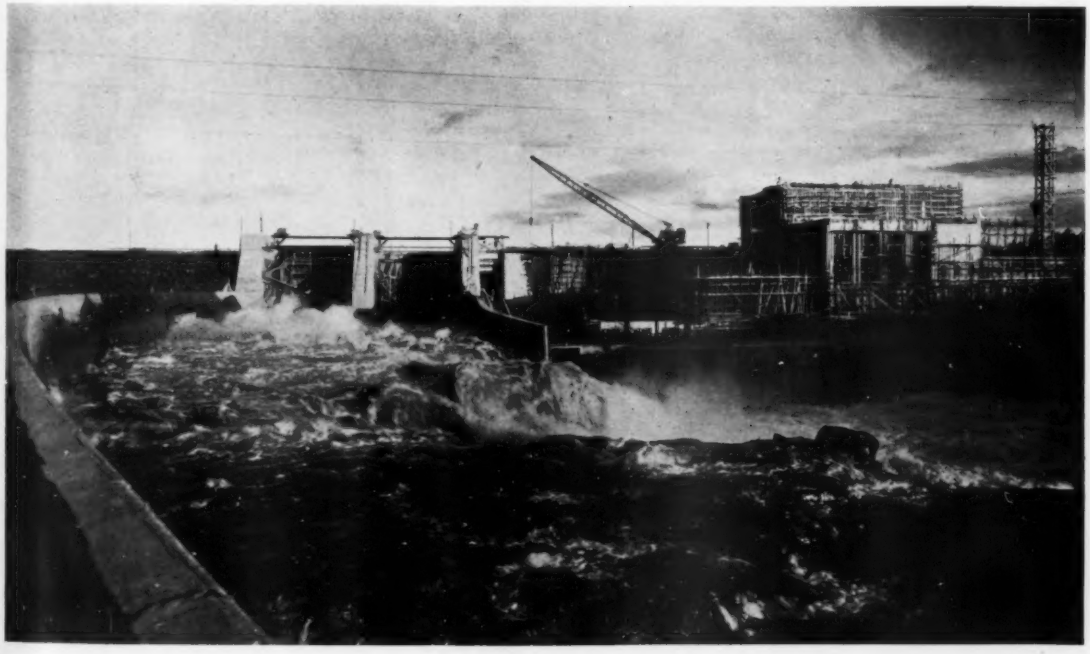


Fig. 2. Iylhämä power plant in course of construction

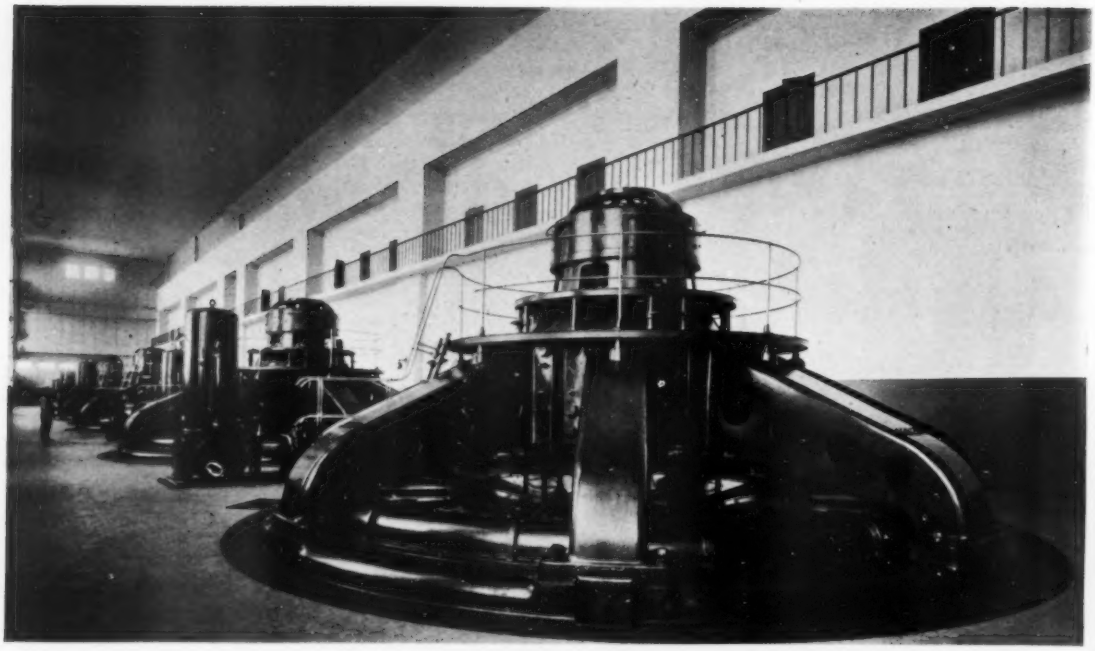


Fig. 3. Machine hall of Imatra power station

for the machinery to be delivered. In a number of instances the machinery has had to be ordered twice from different suppliers and this, of course, has caused additional delay.

As seen from Table IV, 19 of the 27 turbine sets included in the programme are already running. Two of these, viz. one at Kolsi and the other at Kuusankoski were started up before the beginning of 1948. The 19 sets represent a total output of 255 MW and a nominal energy production of 1,705 million kWh per annum. It is estimated that the whole building programme should be nearly completed in 1951. The increase in energy production is shown in Table III.

TABLE III

	Output MW	Million kWh per annum at medium flow	Increase in energy production
1944 - -	415	2500	
1.3.1951 -	670	4205	c. 68%
1951/1952 -	796	4595	c. 84%

In 1952, if the water flow is normal, old plants should produce 2,500 million kWh and the new ones about 2,100 million kWh or in all 4,600 million kWh; in addition, 500 million kWh will be produced by back-pressure steam plants. This energy production of 5,100 million kWh is calculated just about to cover the actual power demand in 1952.

With regard to the development after 1952, it has been planned to get the following plants ready for use in 1953-1954:

River Oulu, Pälli - -	45 MW	230 mill. kWh per annum
River Oulu, Nuojua -	75 MW	390 mill. kWh per annum
River Koitajoki, Pamilo	32 MW	160 mill. kWh per annum
Total	152 MW	780 mill. kWh per annum

In order to avoid any interruption in the development of the energy production corresponding to this demand, it is necessary that all these plans should be carried out in the most rational manner and in the shortest possible time. The work on these plants has already been started.

The capital required for the realisation of this building programme is estimated to be approximately 30,000 million mk, which amount includes about 6,500 million mk for transmission lines and transformer stations for primary distribution, and somewhat over 2,500 million mk for thermal stations. The hydro-electric stations, producing a total of about 2,100 million kWh per annum, and the primary transmission lines would thus require a capital of 27,500 million mk, representing an average investment of about 13 mk for each kWh. This is 20 to 15 times more than before the war. A certain part of this capital was, of course, used during a period when money had a higher purchasing value than at present. The yearly costs for a water-power plant are mostly made up of interest and amortisation charges. At the rather high rate of interest now prevailing in Finland, the price of the new hydro-electric power will be proportionally higher than before the war. Further, the expensive power transmission lines from the plants in northern Finland contribute very considerably to this higher figure. The costs for the three new power plants planned but not included above have been estimated to be 8,500 million mk and for the transmission lines—in some instances of considerable length—to be about 4,700 million mk.

A rational utilisation of the water power naturally presupposes that no steam-power plants will be employed when enough water power is available, and further, that electrical energy will not be used for the generation of steam or for heating purposes when steam-power plants are running. The high price of

the new hydro-electric energy, in some cases possibly exceeding, or at least approaching, the cost of thermal energy, foreshadows economical problems of vital interest to certain private consumers and to some power undertakings. During the present period of transition, when new power plants are started up, it is particularly necessary that due attention should be paid to the price at which power is sold and to putting tariff politics on sound lines.

The projection of the programme outlined above, must be considered ambitious for Finnish conditions. State-owned companies as well as municipal and private undertakers, are participating in these activities. The proportions are such that the State and the municipalities, once the programme has been carried through, will own about 60 per cent. of the hydro-electric power generated, the remainder belonging to private undertakers, chiefly the export industries, which are in special need of cheap water power.

Of the capital required for the realisation of this programme, one fourth consists of foreign currency, which is needed for the purchase of machines, steel and other materials, although the Finnish industry is capable of supplying a noticeable part of the turbine runners, generators, transformers, etc., required, in addition to other constructional materials. It may be mentioned for instance that 22 turbines and eight generators out of the 27 generating sets mentioned in Table IV are being manufactured in Finland.

The total water-power resources of Finland are, in spite of the numerous lakes and water courses, rather limited. A comparison with Sweden shows that the latter country has about 20 per cent. higher precipitation, about 20 per cent. more lake surface, and about 25 per cent. greater water flow in the rivers. The central lakes of the Swedish watercourses are situated about four times higher and the head of the power plants is generally about four times greater than in Finland. The theoretical water-power resources of Sweden are thus about five times those of Finland, which are estimated to be about 30,000 million kWh per annum. About one-third of this can be considered as being economically utilisable, that is, 10,000 million kWh per annum. The area of Sweden is only 33 per cent. larger than the area of Finland.

Fig. 4. Pyhäkoski power station — the largest in the current building programme

The total water-power resources of Finland are indicated in Table V. The power figures given in the table refer to the machine ratings; the energy figures on the other hand represent the maximum amount of energy obtainable per annum at medium water flow. Column 1 shows the utilised water power in 1944 after the armistice and the second column represents the utilised water power after completion of the present building programme (1951), comprising 11 hydro-electric power stations with a total capacity and energy production 390 MW and 2,145 million kWh per annum respectively; and after the starting-up of the planned power plants at Pälli, Nuojua and Pamilo, representing 152 MW and 780 million kWh per annum (1954). The total capacity and energy production of the new power plants will thus amount to 542 MW and 2,925 million kWh per annum. Column 3 indicates the total amount of water power considered to be economically usable.

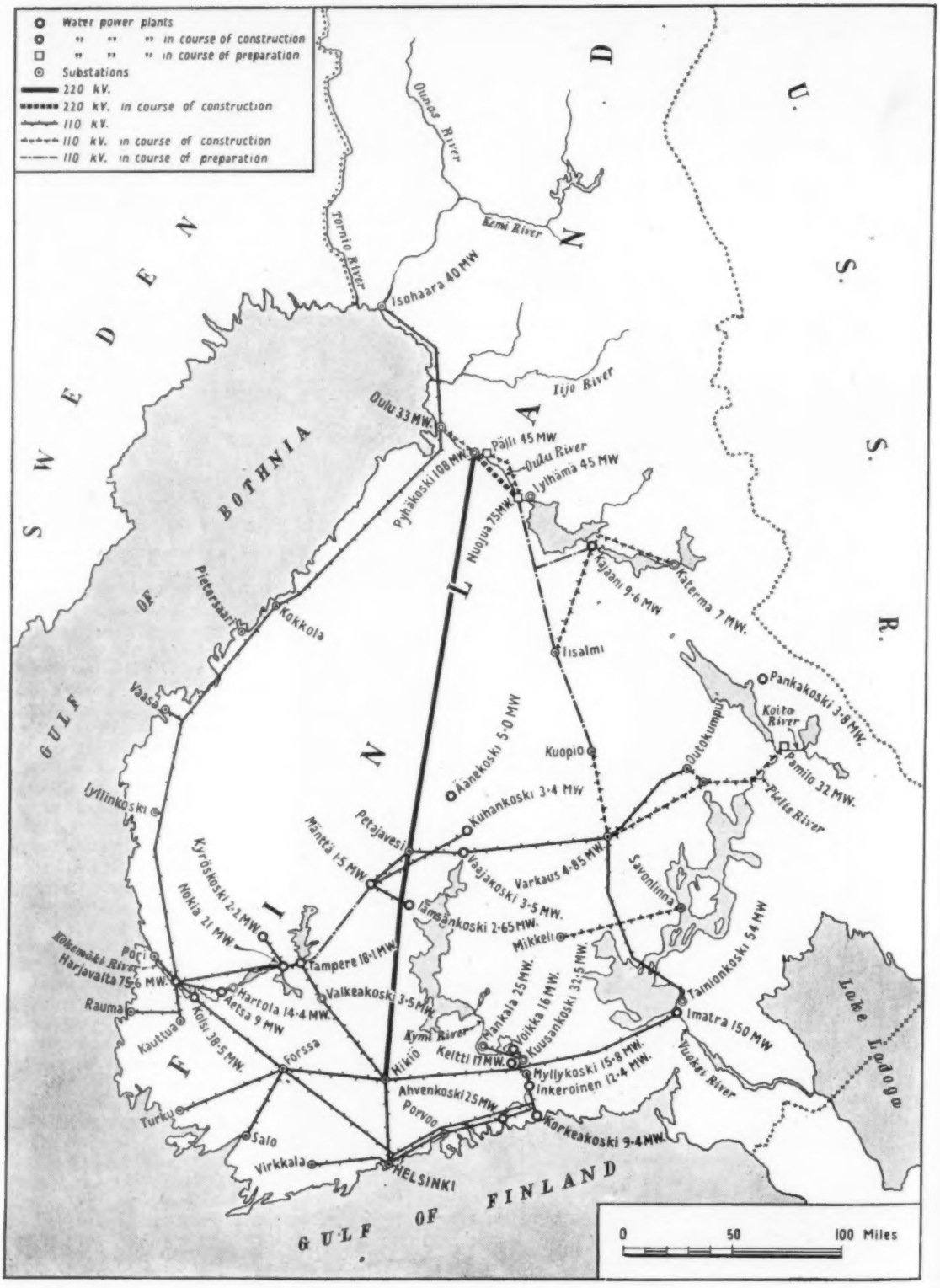


Fig. 5. Sketch map of Finland showing power plants and transmission lines

TABLE IV
WATER-POWER PLANTS IN THE COURSE OF CONSTRUCTION

Power plant	River	Head m	Utilised flow m³/sek.	Generating units		Annual energy production at medium flow appr. millions of kWh	Remarks
				Number	Total output appr. MW		
Kolsi - -	Kokemäki -	12·0	2 × 120	2	24	170	2 units running
Kuusankoski -	Kymi - -	9·5	3 × 120	3	30	185	3 units running
Merikoski -	Oulu - -	10·5	3 × 133	3	33	185	2 units running
Pyhäkoski -	Oulu - -	32·0	3 × 133	3	108	560	1 unit running
Tainionkoski -	Vuoksi - -	8·0	3 × 200	3	39	265	3 units running
Isohaara - -	Kemi - -	12·0	2 × 200	2	40	260	2 units running
Mankala - -	Kymi - -	8·0	3 × 125	3	25	125	2 units running
Jylhämä - -	Oulu - -	12·4	3 × 133	3	45	230	2 units running
Hartola - -	Kokemäki -	6·0	2 × 120	2	10	60	1 unit running
Katerma - -	Ontojoki - -	10·0	1 × 75	1	7	40	1 unit running
Valkeakoski -	Valkeakoski -	4·0	1 × 75	1	3	15	
Imatra - -	Vuoksi - -	24·0	1 × 125	1	26	50	Extension
Total -				27	390	2145	

Table V also shows:—

1. Before the starting-up of the new plants, 25 per cent. of the water-power resources were utilised. The three main rivers in the southern part of the country generated then 95 per cent. of the total power.
2. Considering the plants in course of construction or planned, 65 per cent. of the new water power will be generated in the north, in the rivers Oulu and Kemi; 30 per cent. in the south, in the rivers Vuoksi, Kymi and Kokemäki; and 5 per cent. in Carelia (Pamilo). After the new plants have been started up the three southern main rivers will represent 60 per cent. of the total water-power generation.
3. After completion of the present building programme, 54 per cent. of the economically utilisable water-power resources will have been taken into service. The three southern rivers, Vuoksi, Kymi and Kokemäki are nearly completely utilised and the river Oulu will shortly be utilised to the extent of 80 per cent.
4. The most important resources not yet utilised are situated in the river Kemi, which has a potentiality of 2,500 million kWh per annum, equivalent to the total amount of energy produced at the end of the war. But due to the fact that there are few lakes in this watercourse, the variations in the water-flow are considerable. Furthermore, an expensive transmission system will be required unless large local industrial enterprises could be brought into existence.
5. The remainder of the water-power resources not yet utilised are mostly situated in Carelia in the rivers Pielisjoki and Koitajoki, in rivers discharging into Lake Oulu, and in the rivers Ii, Ounasjoki and Tornio; these correspond to a total energy potentiality of 1,500 million kWh/year.

The map, Fig. 5, gives an idea of the position of the rivers, the existing as well as the new power stations, and of the main transmission network of the country.

Finland is not rich in water power. The resources in the southern part of the country are nearly completely utilised, which compels the power companies more and more to consider long transmission lines from the northern part of the country, and later on, an increasing use of thermal power.

TABLE V
THE WATER-POWER RESOURCES OF FINLAND

	1		2		3	
	MW	Million kWh	MW	Million kWh	MW	Million kWh
River Vuoksi - -	135	1000	200	1300	200	1300
„ Kymi - -	100	650	150	950	200	1200
„ Kokemäki -	115	650	150	900	200	1000
„ Oulu - -	—	—	300	1600	400	2000
„ Kemi - -	—	—	40	250	450	2500
Various streams -	65	200	110	400	350	2000
	415	2500	950	5400	1800	10000

British Constructional Steelwork Association have published a valuable technical brochure under the title "Examples of Structural Steel Design to Conform with the Requirements of British Standard 449: 1948, Part II." It deals with the design of valley beams and stanchions to examples referred to in Part I of this brochure, published last year. The effect of lateral wind forces is discussed.

New Holman Tractair. A leaflet received from Holman Brothers Ltd. refers to the Tractair 13 which has a larger capacity compressor than the current useful machine. The new Tractair has a capacity of 130 cu. ft. per min. (3·7 cu. m.) at a pressure of 125 lb. per sq. in. (8·8 kg. per sq. cm.) and is designed to operate two road rippers or heavy duty rock drills at full pressure.

Hydro-Electric Power Development in Scotland

At the Annual Lecture Meeting of the Supply Section of the Institution of Electrical Engineers, held in London recently, the speaker was Sir Edward McColl, Deputy Chairman and Chief Executive Officer of the North of Scotland Hydro-Electric Board.

SIR EDWARD commenced by touching briefly on the history of hydro-electric development in Scotland, and mentioned that the first stations, other than small private-power plants, were established in 1895, principally for aluminium production, and in that year produced 40 million units a year. In 1906, there were further schemes of a similar localised nature, and all these early developments were carried out without significant public opposition. By 1921, however, a wider public began to take an interest in hydro-electric development, and the opposition hardened. Four Parliamentary Bills were approved, but a number of others were rejected.

The Cooper Committee considered the whole question of water power in Scotland, and the Rt. Hon. Thomas Johnston, then Secretary of State for Scotland, piloted through Parliament the Hydro-Electric Development (Scotland) Act in 1943, which was accepted without a division. This established the Hydro-Electric Board, and on the nationalisation of electricity in 1948, the Board was even more firmly established as the authority for all electrical development in their area, working in close collaboration with the British Electricity Authority.

Sir Edward continued that it was notable that the arrangements under which the former Central Electricity Board had to buy all surplus electricity produced by the Scottish hydro power plants, contained a clause in which the cost of hydro production had to equal the cost of production on the most economical steam station on the Grid, adjusted for Scottish coal costs. This led to the utmost care being taken in the design of hydro power projects to ensure the maximum economy at all stages.

The area of the North of Scotland Hydro-Electric Board covers three-quarters of Scotland and various estimates of the potential hydro-electric power, dating back from 1921 to the present time, have varied from an annual production of 1,880 million kWh to the latest figure of 10 to 12,000 million units per year. These increases in the estimated possible output have been due to change in engineering ideas on technical matters, and also to the fact that the increasing cost of electricity generated in other ways had led to the development of hydro-electric schemes which were not previously considered economical.

At the present time, in view of the flashy nature of Highlands rivers and the fact that many of the schemes do not permit of extended storage, every effort is being made to extend the catchment areas, so that more and more watersheds can be made to deliver their run-offs into the reservoirs for the various power plants.

Sir Edward mentioned the possibility of pumping, and said that it was sometimes economic to lift water 100 feet so that it could later drop through a thousand feet. Pumps were now 85 per cent. efficient, and he said that at Lawers (a plant with a very high head of 1,362 ft., and where a 30,000 kW Pelton set was being installed) the Board were also providing a 12,500 kW pumping set.

The speaker also mentioned that the storage available represented about 20½ per cent. of the total output yet considered in terms of impounded water. There was also ground storage, which could not be exactly assessed, but was likely to be of the order of 35 per cent. of the impounded water.

Dealing with the designs of station employed by the North of Scotland Hydro-Electric Board, Sir Edward said that many of the stations were using the horizontal Francis in place of the vertical design, since with a vertical turbine of this type a very considerable height of building had to be provided solely for the provision of a crane for maintenance operations. A considerable saving in this respect was effected by the use of the horizontal design, which also made for simplification of the civil work, and effected a saving in respect of the work of the relatively few skilled craftsmen available for civil engineering of this type.

One station was of the outdoor type, and here a special design of crane had been evolved, as otherwise the gantry would be unsightly. This crane was of a telescopic nature and folded away into an inconspicuous mounting when not in service.

A number of stations had only a single generating unit. This simplified remote control and also had a number of advantages in regard to staffing. The provision of living accommodation, in remote Highland areas, for the different social and professional grades of workers and their families associated with the operation of a hydro-electric scheme, provided considerable difficulty. By centralising control from an existing town, of a number of single-unit stations, this problem and that of the educational problem of children situated in very widely scattered districts which were frequently cut off altogether in winter months, was to a large extent solved. Sir Edward mentioned that there were cases, where a hydro station had involved the provision of staff at a remote point, and where the local Education Authority had had to provide the services of a full-time teacher to educate a single child.

Another aspect of station design was the use of Kaplan turbines for very high heads, in particular for 188 ft. in Invermoriston.

The North of Scotland Hydro-Electric Board had paid very considerable attention to the amenities of the district, and had carried out many extensive additions to the bare minimum necessary for a hydro-electric scheme, in order to preserve the amenity value of the Highlands. For instance, practically all

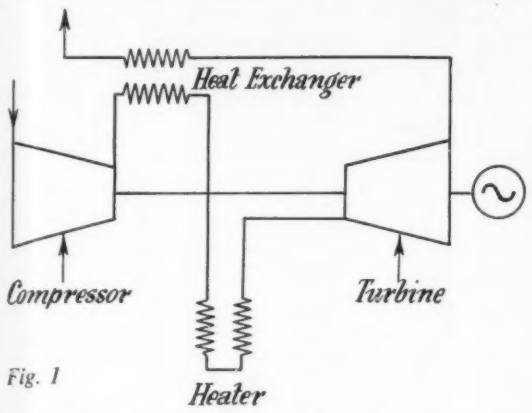
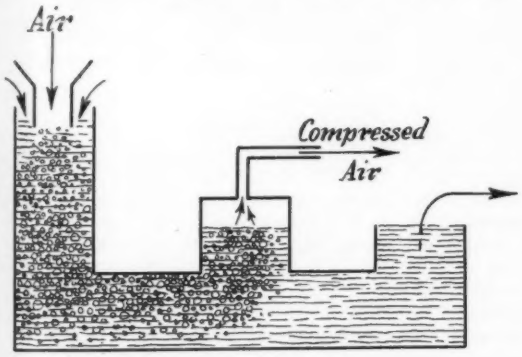


Fig. 1

the buildings had been faced with local stone over a reinforced concrete shell; underground stations were being installed in at least two of the schemes; pipelines were placed underground in three schemes; and the greatest care possible had been taken to ensure, by fish ladders and fish lifts, that the salmon in the Highland rivers could reach their spawning grounds and could return to the sea. Much thought had been devoted to this latter aspect.

Regarding the type of dam employed, labour and cement shortage had led to the consideration of utmost economy in both these directions, and Sir Edward was of the opinion that the buttress and rock-fill types of dam were, in general, to be preferred. Experiments were in progress with the use of blast furnace slag with cement, and it was thought



Hydraulic Compressor

Fig. 2

that this offered great possibilities in regard to economy in the latter material. A close watch was being kept on similar experiments in France.

Turning to other sources of energy in the Highlands. Sir Edward said that there were obvious possibilities for the use of tidal power on the West Coast, but this had not yet been fully examined. The schemes so far considered, however, were obviously more costly than the normal type of hydro-electric project.

Turning to wind power, he said that although this could not provide firm kilowatts, it could be used to advantage in conjunction with a diesel plant, or with

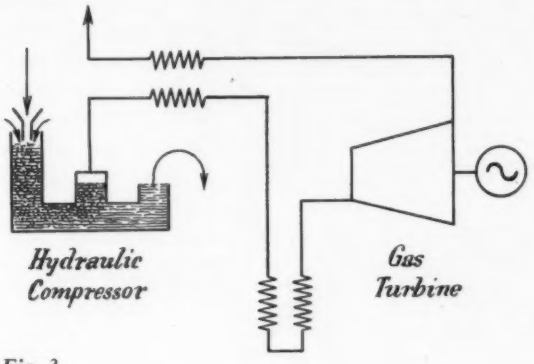


Fig. 3

a restricted hydro-power station. The 100 kW experimental wind generator on the Orkney Islands would be commencing operation shortly and would run in parallel with a diesel generator. The alternator was of the induction type and the diesel generator would supply the magnetising current.

He also touched on the interesting project of using hydro power in conjunction with the peat resources of Scotland. A gas turbine would be employed but had the obvious drawback that the compressor of a straightforward, open-cycle gas turbine generator absorbed nearly 60 per cent. of the power generated by the turbine (Fig. 1). On the other hand a hydraulic type compressor could utilise a head of water to suck in air in one leg of a U-shaped vessel, and this air, which is in bubble form, would rise in a special

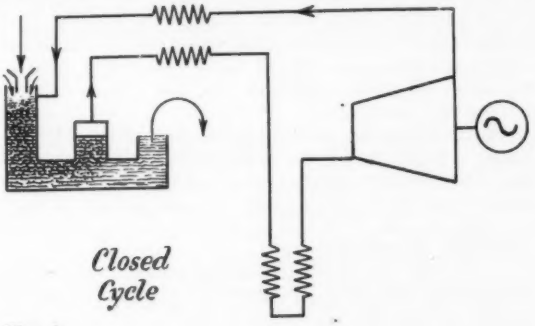


Fig. 4

chamber at the centre of the U and would be compressed by the difference in head between the inlet on the long leg of the U and the outlet on the shorter leg (Fig. 2). This air could then be taken to a gas turbine, thus dispensing with the normal rotary compressor. The hydraulic compressor was 50 to 75 per cent. efficient, and by its aid a given gas turbine could give 2 to 2½ times greater output (Fig. 3). The use of peat as a fuel, coupled with the hydraulic compressor (Fig. 4) would be likely to provide a considerable amount of power.

Physical Properties and Drillability of Rocks

PART TWO—Having reviewed some established methods for determining physical properties of rocks R. Shepherd, B.Sc. (Eng.), Assoc.M.I.Min.E., F.G.S., now gives the results of hardness tests made with the Shore schleroscope, describes investigations on rock toughness, and outlines apparatus and initial preparations made for a study of drillability.

IT should be understood that the schleroscope does not give readings which indicate the hardness values for rocks. Each schleroscope has an arbitrary scale and gives values or rebound readings which can only be used to compare hardnesses of rocks. Thus a granite may give a reading of 90 on one schleroscope and 75 on a second instrument, so that all tests, if they are to be comparative, must be conducted on one instrument. Wolansky makes an interesting comparison between results obtained by the use of various makes of schleroscope and concludes that the Shore instrument gives the most reliable results[6].

Approximate 2 in. cubes were used in the actual tests conducted by the author, the samples being taken from the larger 12 in. blocks and cut true with a rock-cutting wheel fed with diamond dust, and afterwards polished to give smooth faces. The cubes were dried at laboratory temperature for two to three weeks before use.

As the mineral content in most rocks may vary along one face of a cube, it was realised that one reading would not suffice for each sample. Accordingly, each surface was gridded by light markings to form ½ in. squares. A test was made at each grid point and the mean Shore number found from the totals and number of observations made. This method allows for the possibility of test points being located on softer or harder minerals and the effect of error is therefore minimised.

Probably the largest error possible with the schleroscope is that due to the human element. Ability to note the correct height of rebound quickly is a great asset, which is not acquired without practice.

Analyses of results

As already stated the arithmetic mean of all values recorded is computed, the method being as follows:—

$$h = \frac{h_1+h_2+h_3+h_4+ - - - - - +h_n}{n}$$

where h = arithmetic mean.
n = number of readings.
$h_1 - h_n$ = individual readings.

The arithmetic mean h is the average of what may be extremely high and very low readings, and the standard deviation δ is equivalent to:—

$$\sqrt{\frac{(h_1-h)^2+(h_2-h)^2+(h_3-h)^2+ - - - +(h_n-h)^2}{n}}$$

i.e., $$\delta = \sqrt{\frac{\Sigma d_a^2}{n}}$$

where d_a = deviation of each reading from the value.

therefore $\% \delta = \frac{\delta}{h} \times 100.$

Table I is a summary of the results obtained on various rock samples with the instrument.

TABLE I—SUMMARY OF RESULTS OBTAINED WITH SHORE SCHLEROSCOPE

Rock	Locality	No. of Readings	Shore No.	Deviation δ	Percentage Deviation (% δ)
Syenite ...	Leicestershire...	67	92·8	6·84	7·36
Sandstone ...	Parkgate Rock. Yorkshire	62	66·1	2·77	4·18
Bind ...	Dunsil Seam, Yorkshire	78	52·9	4·26	8·06
Hæmatite ...	Cumberland ...	28	85·1	3·77	4·44
Gritstone ...	Derbyshire ...	46	63·7	4·68	7·34
Limestone I	,, ...	46	78·6	3·46	4·43
,, II	,, ...	53	70·2	7·21	10·25
,, III	,, ...	40	64·5	9.98	15·47
,, IV	Northants ...	31	64·0	4·15	6·48
Granite ...	Cornwall ...	38	92·8	12·76	13·75
Ironstone ...	Northants ...	30	50·8	4·22	8·29
Coal (right angles to cleat) ...	Parkgate Seam. Yorkshire	29	82·5	3·36	4·08
Coal (parallel to cleat) ...	Parkgate Seam, Yorkshire	29	81·5	3·32	4·08

The results given in Table I disclose several interesting facts. Rocks having large crystals of minerals exhibiting widely varying degrees of hardness, give a greater deviation than the more homogeneous rocks. For example, granite has the high deviation figure of 12·76, while hæmatite gives 3·77. Thus granite, syenite, crystalline limestone II, calcitic-veined limestone III, have high deviations as compared with coal, black fine-grained limestone I, etc.

Syenite has the same hardness values as granite, although the composition is slightly different; the former having a lower silica content being an intermediate rock and granite an acid rock. Both, however, are of plutonic origin and have coarse grains due to slower rates of cooling during formation. In the present samples syenite has the finer grain and this may account for the lower deviation. Thus finer-grained rocks exhibit a smaller deviation from the mean value.

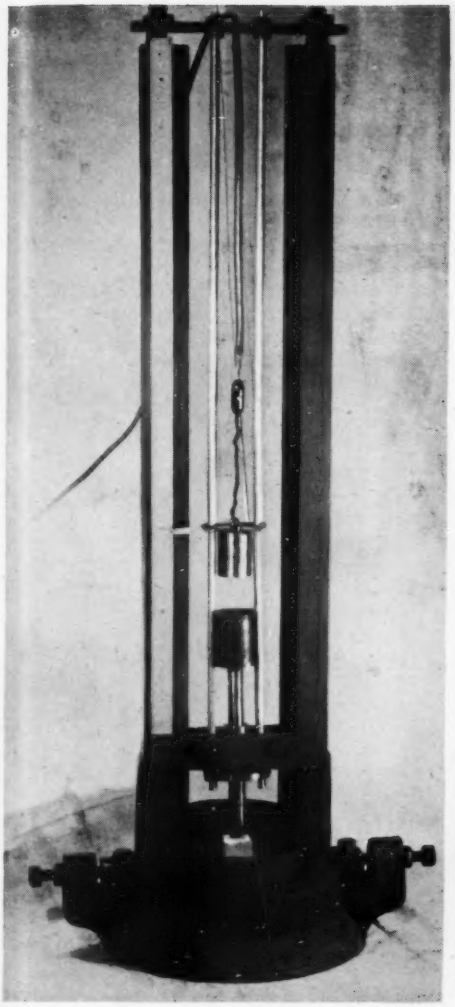


Fig. 3. Impact machine for toughness tests

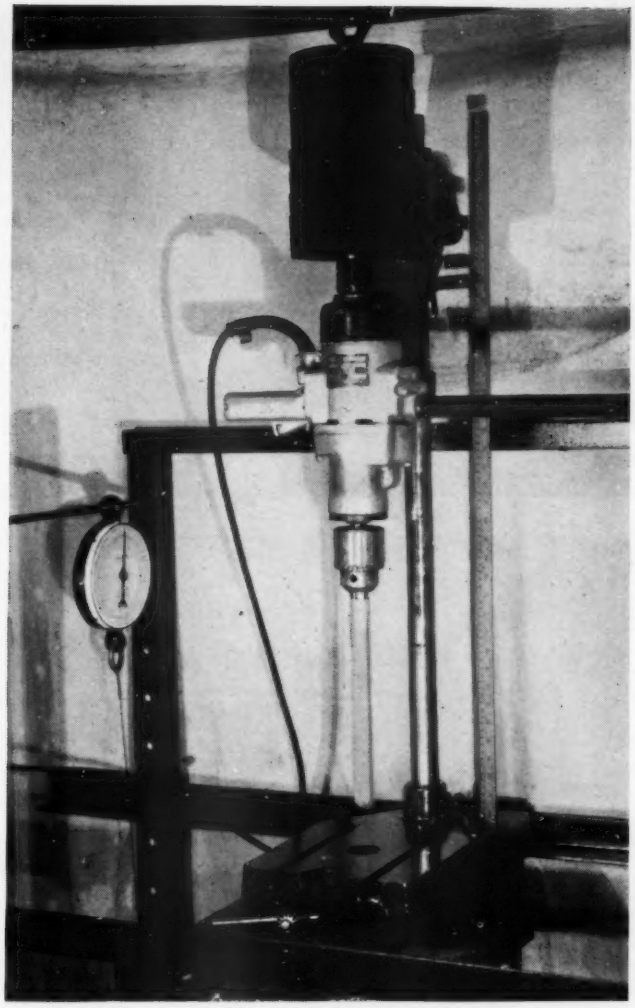


Fig. 4. Machine drill used in the tests

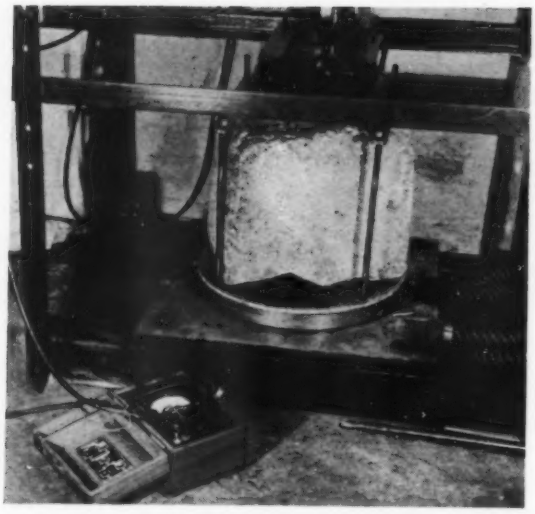
The percentage deviation expresses the deviation as a percentage of the hardness value and may be high for softer rocks which may have, however, a low deviation figure. Ironstone, for example, gives a reasonably low deviation (4·22), but the percentage deviation is higher than for a much harder rock such as syenite.

Work hardening

The first reading on a particular grid point may be low and if observations be repeated on the same spot a number of times, the values will tend to rise progressively to a maximum. This, in the author's opinion, may be a form of work hardening in rocks. After a period of fairly constant maximum readings the readings will decrease. This temporary reduction may be due to binding in the crater or to the sluggish action of broken particles absorbing the energy of the blow. After another period of low readings the maximum value is again progressively attained. The problem appears to be one of deciding which value to take as the Shore number, the abnormally low initial reading or the more constant maximum value. This point will be dealt with later, but for the present it is sufficient to state that all forms of drilling in rocks effect a certain amount of the so-called work hardening because a compressive force or thrust must be exerted, and in percussive drilling particularly, impacting is prevalent.

Both minimum and maximum readings were recorded for each specimen and the number of impacts required before the maximum value was noted. Table II gives the results of these tests.

It will be seen that for most rocks there is a considerable divergence between the minimum and maximum values, the divergence being greater for rocks having lower maximum schleroscope readings. Work hardening is, therefore, more prevalent in the rocks having lower maximum values, the maximum Shore number of the rock having a high percentage increase being reached only after grain consolidation has been effected. Gritstone, for example, may be described as a loosely-grained rock, the grains not being firmly embedded in the matrix, and in this case work



hardening compacts the grains and brings the value nearer to that of a sandstone, which has a similar composition, but a more compact grain arrangement.

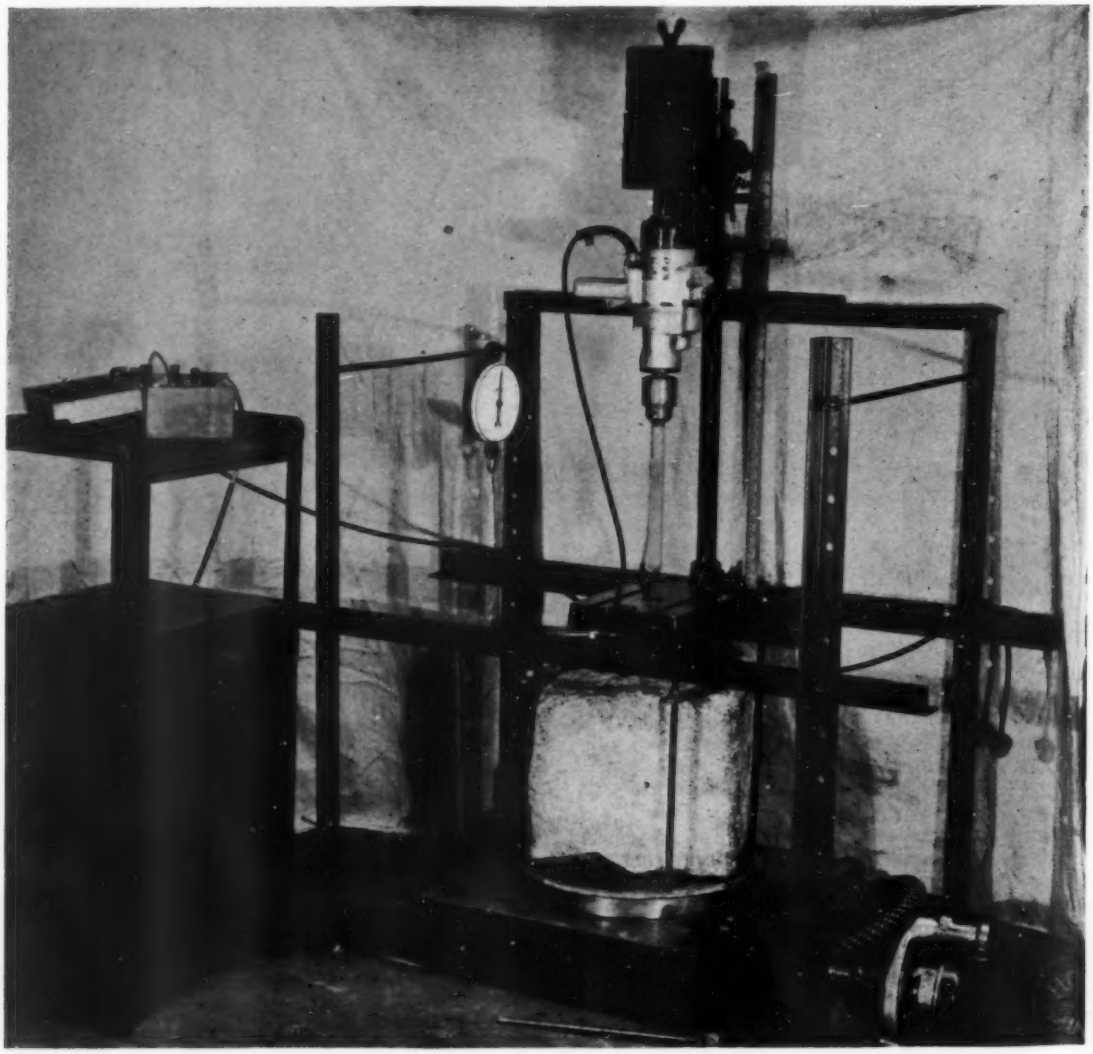
The average width of impression at the impact point on each specimen was determined, the actual measurement being made by observation with a horizontal traversing microscope, but no deduction could be made as the widths seemed to have no relationship to other values.

Toughness of rocks

Toughness of rocks depends on the strength of the rocks and this is governed by the efficiency of the matrix in binding together the grains or minerals comprising the bulk of the rock. In addition, grain strength or mineral toughness is a function of the

Fig. 5 (left). Close-up of the torque table

Fig. 6 (below). Full view of the test machine



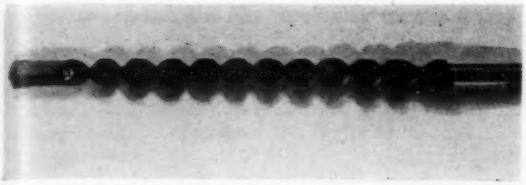


Fig. 7. The $\frac{5}{8}$ in. spiral drill with tungsten-carbide tips

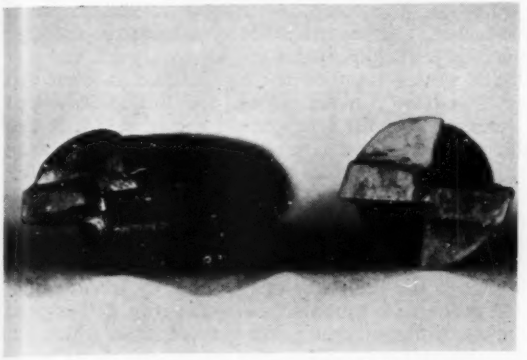


Fig. 8. Worn and new spiral drill nuts

rock toughness. The toughest rocks comprise those having strong minerals embedded in a strong matrix or cement. In addition the shape of the grains governs the toughness, since a rock which has angular grains is subjected to a greater degree of consolidation under impact than one which has rounded grains.

Fig. 3 shows a photograph of a machine which was constructed in order to measure the degree of toughness of the rock subjects under test. It consists of a cylindrical hammer of 2 kg. weight, grooved longitudinally so that it is constrained to fall vertically between parallel vertical brass guides of $\frac{1}{2}$ in. diameter. A 1 kg. plunger, free to move in a cylindrical guide, rests on the specimen $1\frac{1}{2}$ in. cube, the end in contact being equipped with a renewable Brinell ball of 1 cm. diameter. The upper end of the plunger is fitted with a renewable hardened-steel cap, and the contact end of the hammer is fitted with a renewable circular insert of hardened steel.

When in use the hammer is dropped from a height of 1 cm., 2 cm., etc., until the specimen just fractures. Quick release of the hammer is effected by an electro-magnet which is operated on 110 V d.c. supply. The height of fall at the moment of rupture of the specimen is taken as the toughness factor.

TABLE II—WORK-HARDENING INDICATIONS

Rock	Average No. of Impacts on Grid Point to Reach Maximum Value	Mean Initial Reading	Reading Mean Initial	Percentage Increase
Granite ...	1	92·8	92·8	—
Syenite ...	9	81·1	92·8	14·4
Hæmatite ...	4	79·3	85·1	17·3
Coal	7	68·3	82·0	20·0
Limestone I ...	7	58·9	78·2	33·3
,, II...	6	53·6	70·2	30·9
,, III	5	48·2	64·5	33·0
,, IV	7	45·5	64·0	40·9
Sandstone ...	9	35·5	66·1	83·4
Gritstone ...	9	21·2	63·7	200·0
Bind ...	3	29·0	52·9	82·1
Ironstone ...	14	18·6	50·8	173·7

It was obvious from early results obtained that there was no relationship between hardness and toughness. The green carbonaceous ironstone has been shown to have a work hardening property under the impact of the schleroscope hammer. On the other hand, bind does not exhibit this property to such a great extent, but the ironstone gives a toughness value of 12·8 as against 7·9 for bind. Ironstone in becoming consolidated under impact tends to absorb the blow to a great extent, and finally yields as the consolidation process ceases and the impact force increases. Bind being more brittle is less tough and breaks more easily under impact.

In the author's opinion toughness of rocks is a more important property when percussive drilling is being studied, as the conditions pertaining to rotary drilling are different. Percussive drilling may result in local work hardening before the rock yields, whereas rotary drilling works on the reverse principle, a steady applied load, free from impact, and therefore free from the hardening properties.

Specific gravity

Specific gravity affects the rate of clearance of cuttings to a greater extent from down holes than from up holes, and horizontal holes can be more rapidly cleared of cuttings during drilling when the rock subject has a lower specific gravity. For all holes however, whether the clearing agency is spiral drill rod, water flushing or compressed air, or simply gravity, this is true.

The ordinary specific-gravity bottle method of determination was used to find values for the rocks tested and Table III lists the information.

TABLE III

	Specific Gravity
Granite	2·58
Hæmatite	4·23
Bind	2·66
Gritstone	2·54
Limestone I	2·60
,, II	2·64
,, III...	2·78
Syenite	2·74
Sandstone	2·56
Ironstone	3·13
Limestone IV	2·61
Coal	1·21

Drillability

The relationship between the physical properties of mine rock and the drillabilities of such rocks had not previously been investigated to any great extent. There have been many field drilling tests and most drill and bit manufacturers have conducted efficiency tests in their own works. In Germany during the war when hard metal-tipped bits were being exclusively adopted, trials on different rocks were carried out and relative drillabilities were computed[7]. In the author's opinion, such tests carried out in a normal routine manner, either in underground workings or on the surface, are not conclusive as they cannot be used under precise controlled conditions. The difficulties involved are:

(1) the applied pressure, thrust or load may vary considerably and is subject to the human element,

(2) water flushing is efficient, but the supply may fluctuate during a working shift,

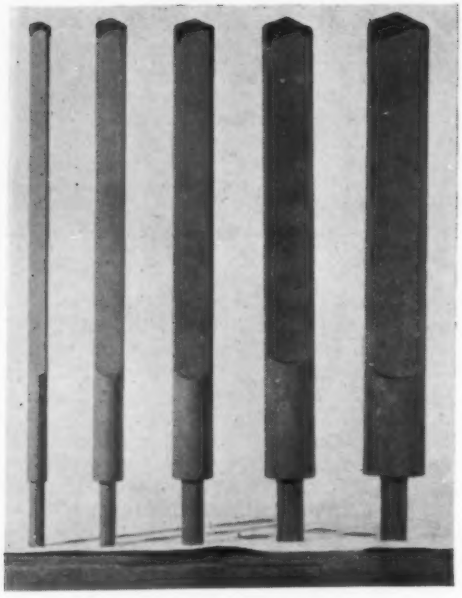


Fig. 9. Plain-shank test drills

(3) the air pressure may not be constant and comparative conditions may not be easy to acquire,

(4) it is difficult to keep an accurate check on drill-bit wear,

(5) the strata are liable to variation, particularly in cross-measure drifts; planes of weakness and slips occur thus reducing the value of observations.

Finally, the requirements of production must have priority and this fact may lead to constant modification of the method of operation during the tests.

These considerations helped the author to decide that laboratory scale tests at the outset would enable standard controlled conditions to be obtained. It was further decided to use the electric rotary method of drilling, as control and measurement is simpler than when associated with compressed-air operated machines. A choice between horizontal and vertical drilling presented itself but it was apparent that the drilling of vertical down holes would enable drillability to be studied under the worst conditions. Furthermore, there is really no satisfactory method of providing a reliable horizontal thrust that can be varied easily, except by the use of horizontal hydraulic rams.

The object behind the drillability tests to be described was not to reproduce the conditions obtained in practice, but to compare the resistance to penetration of several different rock subjects and to correlate the results with the physical properties. To obtain reliable comparison it was necessary to drill each rock under precisely the same conditions.

Description of the machine used

The apparatus used for the laboratory drillability tests was constructed about a Wolf bench drill, fitted on a stand. Fig. 4 shows a close-up view of the mounting of the machine. The type of bench drill selected was equipped with a hand lever arrangement for pressure application, but gave only four inches of movement. The lever was dispensed with and, by fixing a central spindle on the head of the machine and a carrying plate, the machine was adapted for the use of cheese-weights. The lever-handle mechanism was pivoted about an attachment rigidly clamped to the main column and allowed the machine to descend vertically for a distance of four inches and also prevented side movement. To allow vertical travel in excess of four inches, the clamp had to be released, but this permitted sideways movement which was not required. Accordingly, a vertical slot $\frac{1}{4}$ in. wide, $\frac{1}{4}$ in. deep, was milled the full length of the column and a small set-stud inserted to guide the machine vertically during its downward travel.

The power supplied to the machine is measured by a wattmeter in the circuit. The torque developed is measured by the arrangement shown in Fig. 5, and the rock specimen is mounted and clamped on an 18 in. dia. steel table, which in turn is mounted on 48 $\frac{5}{8}$ in. dia. steel balls constrained to move in a circumferential groove. The central spindle of the table runs in a ball race. A spring balance records the tangential force exerted during drilling, and is connected to the periphery of the table by a wire cable. The machine is mounted, complete with its bedplate, on two horizontal supporting angle irons which can be adjusted in height to suit the height of the specimen. A boxwood scale is mounted vertically so that depths of penetration can be measured, the distances being indicated on the scale by a brass pointer bolted to the machine. Fig. 6 is a photograph of the complete arrangement.

It was decided to use tungsten-carbide-tipped drills for the following reasons :—

(1) Gauge wear, while being measurable, would be less than for ordinary steel bits.

(2) Deterioration of the cutting edges would be slower than for ordinary steel bits and it would be easier to maintain standard conditions.

(3) The drills would withstand to a greater degree the penetration of hard and abrasive rocks.

Two types of drills were acquired, (*a*) spiral drills $\frac{5}{8}$ in. in diameter with tungsten-carbide tips, as shown in Figs. 7 and 8, (*b*) plain-shank tungsten-carbide-tipped drills of diameters $\frac{1}{2}$ in., $\frac{3}{4}$ in., 1 in., $1\frac{1}{4}$ in. and $1\frac{1}{2}$i.n Photographs of these are shown in Figs. 9 and 10.

One major difficulty which had to be overcome was the removal of cuttings and, as standard conditions were essential, water flushing with all its eccentricities was not considered as suitable. It was thought that the spiral drill was the complete answer to the problem for the proposed tests. All holes were to be vertically downwards so the removal of cuttings was of paramount importance.

Preliminary tests with the machine

In order to establish the most suitable method for all tests with the machine, preliminary trials were carried out on a block of coal-measure sandstone (Parkgate Rock) of approximately 1-foot cube.

At the outset, the spiral drill proved unsatisfactory for hole cleaning. In addition it was weak in section and heavy loading soon caused the drill to assume the condition of an eccentrically loaded column. It was not surprising therefore that an increase in applied load resulted in a decrease in penetration speed as Table IV will show.

As heavier loading was necessary in order to study the effect on penetration speed, etc., a further de-

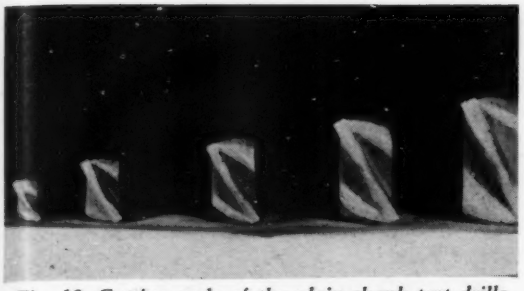


Fig. 10. Cutting ends of the plain-shank test drills

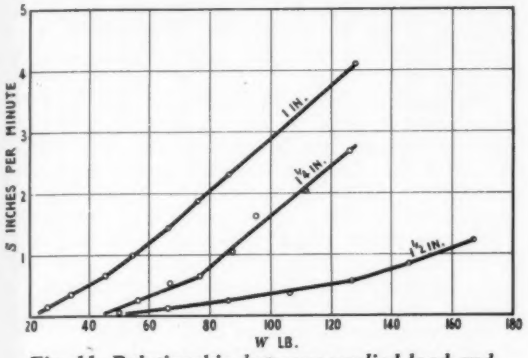


Fig. 11. Relationship between applied load and penetration speed for Parkgate rock

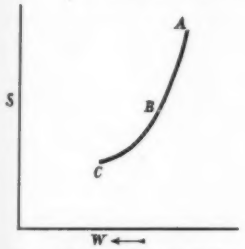


Fig. 12. Characteristic for decreasing load in abrasive rock

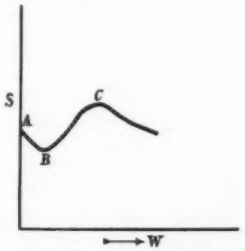


Fig. 13. Characteristic for increasing load in abrasive rock

crease in the latter was to be expected. Fig. 8 shows a comparison between a worn bit after only a few inches of drilling and a new bit.

Plain shank drills were substituted for the spirals, but provision for hole cleaning was made. A vacuum cleaner was used with a flexible rubber tube so that it could be fixed near the hole collar. This was very successful, and the cleaner was used after each drill run. It was found that for holes to a depth of 9 to 12 in. the cleaner would keep the bit clear, the cuttings from a limited drill run being kept in suspension.

TABLE IV—PENETRATION SPEEDS WITH SPIRAL DRILLS

Pressure on machine	*Penetration Speed in. per min.*
nil	0·541
6	0·108
12	0·059

In order to effect adequate hole cleaning during drilling it was realised during the preliminary trials that measurement of penetration speed over a very short depth would be preferable, for the object in view, to measurements taken over the continuous drilling of a 6 to 12 in. hole. Accordingly 0·5 in. to 0·6 in. was fixed as the maximum depth to be drilled for each run, the drill being removed each time and the hole cleaned out by suction.

The drill was weighed carefully after each run and the bit gauge checked by micrometer.

Results in the preliminary trials were very erratic, and they had to be studied carefully in order to improve the methods used. As a result of the early failures and consequent investigations, facts came to light which would not have been evident had the correct technique been adopted at the outset.

The ¼ in. and ⅜ in. drills were used first and the applied load increased in each case from zero to a higher value. Owing to the fine edges being removed from each new bit at an early stage and noticeable bevelled edges resulting, early losses in weight were noted. It was found that with higher first loading and decreasing load the initial weight loss was very much less. Table V summarises the results of the preliminary tests on bit wear.

The results in the table indicate that the following conclusions might be formed.

(1) Light loading of rotary drills results in greater bit wear. It appears that due to lighter loading there is a corresponding increase in chatter and vibration and this probably results in greater bit wear. Heavy loading keeps the bit up to its working point and vibration is very much reduced.

(2) Least wear results from constant maximum loading.

(3) Greater wear is caused by commencing with light or zero loading and increasing gradually to the maximum than with decreasing the load from the maximum. Increased initial wear of the new cutting edges results more from the former cause.

(4) Larger size bits suffer a greater loss in weight per inch of cutting edge per inch drilled than the smaller bits. Obviously the outer edges of a large bit cut more rock than those of a smaller bit.

As a result of the above observations it was decided to test the rock subjects with various bit sizes, but for very abrasive rocks only the smaller size bits

TABLE V—DETAILS OF LOSS IN WEIGHT OF BITS DUE TO WEAR

Bit Size (in.)	Loading (lb.)	Method of Loading	Weight of Bit (g.)		Loss in Weight (g.)	Loss in Weight per inch of cutting edge (g.)	Depth drilled (in.)	Loss in Weight per inch cutting edge per inch drilled
			Initial	Final				
¼	0–90	Increasing ...	186·35	185·62	0·73	1·46	13·99	0·1042
¼	126	Constant ...	184·65	184·62	0·03	0·06	4·10	0·0146
¼	0–104	Varied ...	424·45	423·35	1·10	1·48	17·09	0·0866
¼	126–56	Decreasing ...	422·55	422·51	0·04	0·052	3·86	0·0135
1	104–24	Decreasing ...	741·50	740·70	0·80	0·80	11·19	0·0715
1½	128	Constant ...	1142·0	1141·9	0·10	0·08	6.61	0·0121
1½	128–44	Decreasing ...	1651·1	1650·8	0·30	0·20	4·54	0·0441

could be used. Rocks having low abrasive properties could be drilled with all sizes of bits in rotation.

Relationship between applied load and penetration speed

During the preliminary tests on coal-measure sandstone it was noted that there appeared to be a linear relationship between the applied load and the penetration speed. This appeared to be the case in an abrasive rock even when increasing the load from zero to the maximum, but if the test was repeated, the penetration speeds were lower, but the slope of the line was approximately the same.

Thus if W = applied load in lb.

S = penetration speed in in. per minute.

then $S = KW + C$

K is the slope of the line at any point and may be taken as a constant for a particular rock. C, the intercept on the S axis is the value of the penetration speed due to the weight of the machine alone which is 40 lb. The K values are not the same for all bit sizes used in the same rock. Fig. 11 shows graphs of S against W for Parkgate Rock and it will be noted that the value of K is lower for larger bits than for small bits.

Importance of initial wear

Very abrasive rocks produce immediate wear on the bit and this is inversely proportional to the load applied. Thus, early in a test, K will have a high value due to bit wear, but when initial wear has ceased and the bit retains a normal cutting edge, for a time K will have a lower value, but will be constant. Bit wear is still operating during this period, but at a slower rate as the edge is minutely bevelled and a greater surface of bit is thus presented to the rock subject compared with a sharp edge of a new or reground bit.

Fig. 12 illustrates a hypothetical case for a very abrasive rock.

The rate of fall in S over the distance AB of the curve is due to the prevalence of two factors, *(a)* initial wear of the cutting edges, *(b)* gradual increase in rock resistance during collaring of the hole and also in some cases due to the decrease in the effect of surface weathering in depths.

It was decided, in order to combat these initial obstacles to precise measurement, to *(a)* collar the hole over a short depth with an old bit of the same diameter as the one to be used in the test: *(b)* to ignore the first depth of measurement of 0.5—0·6 in., i.e., to measure the penetration speed over the part of the graph BC.

Conversely, K values are measurable and equally applicable to drilling with increases in applied loading, but only in the case of non-abrasive rocks which give K values equal to those obtained with decreasing loads. With very abrasive rocks the diagram will not be as in Fig. 12. Theoretically the relationship between S and W should be a straight-line law, but this in most cases is not true owing to the prevalence of the factors already considered.

Fig. 13 shows the variation in S for increases in W. The value of S falls from A to B until collaring is complete, and then increase in W produces an increase in S, but at the same time bit wear is taking place, and to a greater extent than with decreasing loads, since light loading in rotary drilling produces greater wear. The wear in this case is more rapid and the maximum value of S may be reached at C, depending on the rate of increase of applied W. Further increases in W may combat further wear and a stationary value of S may result. On the other hand the value of S may fall. The distance drilled before the conditions at C operate is a function of the abrasiveness of the rock.

As a result of this reasoning based on actual preliminary tests it was decided to test abrasive rocks only with decreasing values of W.

Critical Point

On examination of S/W graphs it was noted that there was a pronounced abrupt change of gradient occurring at certain well-defined points. Thus two values of K can be deduced for each rock tested, a higher value above the critical point and a lower value below.

This gradient change indicates that each rock has an optimum loading above which there is a rapid increase in penetration speed for increases in load or conversely below which there is a slower decrease in penetration speed for decreases in load. It was appreciated that very tough rocks may not exhibit a gradient change within the limits of the loading of the machine. Accordingly it was adapted for the loads to be increased from 126 lb. to a new maximum of 400 lb.

The following conclusions were reached:—

(a) the smaller diameter bits produce higher K values both below and above the critical point;

(b) the smaller diameter bits exhibit a gradient change on the S/W curves at a lower critical point than in the case of the larger bits.

The two gradients have no relation to the two parts of the curve AB and BC in Fig. 12 as this indicates conditions at the start of drilling only.

Theoretically there is no limit to the penetration speed corresponding to increased loading, but in practice a maximum penetration speed may be reached due to inefficient clearing of the cutting edges resulting from the rapid production of broken material.

(To be continued)

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Commercial Diesel Trucks. A well-produced booklet received from Sentinel (Shrewsbury) Limited gives details of the construction and operation of their diesel-powered road trucks and mentions some of the leading manufacturing firms using this form of transport.

Lead-Treated Alloy Steels. A brochure entitled "Some Notes on Alloy Steels Containing Lead" has been received from Samuel Fox & Co. Ltd., a subsidiary of the United Steel Companies Limited. It gives much useful information on the properties of alloy steels containing lead.

A Joint Engineering Conference

The three senior engineering institutions in Great Britain—the Institutions of Civil, Mechanical and Electrical engineers—held a Joint Engineering Conference in London during the early part of June.

THIS joint conference was opened by the Rt. Hon. Richard Stokes, the Lord Privy Seal, who stressed the responsibilities of engineers in the present world state, adding that they must seek to do everything possible to find substitutes for materials in short supply. He felt that if more engineers were engaged in the government of various lands, the world would be a better place.

The technical sessions in which reference was made to hydro-electric matters were those in which Sir John Hacking spoke on "The Generation, Transmission and Distribution of Electricity" and Sir William Halcrow's paper on "The Development of Hydro-Electric Schemes."

The inception of the conference was linked with the Festival of Britain, the aim of which was to record the contributions made by engineers and scientists of this country during the past hundred years. Thus the papers tended to be of a general character and in each case commenced with an authoritative summary of the work of the last century.

Sir John Hacking (Deputy Chairman of the British Electricity Authority) surveyed the growth of the interconnected network which now covers England, Scotland and Wales. In connection with hydro-power development in the North of Scotland, his paper showed that whatever amounts of energy were generated in any part of the country, they could be usefully used anywhere else; and the coming of the 275 kV super-grid would make this even more certain. He gave detailed descriptions of the operation arrangements used in the control of the present grid, and showed how highly integrated and yet flexible the system had become. The telephone network of the Post Office was very largely used in place of the carrier-current systems widely employed in other countries, although short-wave radio is now used in certain cases for regular control links.

Sir John Hacking's paper was naturally concerned more with the progress of thermal generating plant than with hydro-electric equipment: but in his resumé of the present state of development of generating plant, he said: "Most big water turbine driven alternators now operating run at about 75 to 200 r.p.m. Some very large machines are now built, including the 108,000 kVA 120 r.p.m. vertical machines for the Grand Coulee dam in the United States. These generators weigh about 630 tons."

The paper by Sir William Halcrow dealt principally with three hydro-electric schemes, which he took as examples of developments which had taken place during the last century. These were two in Scotland and the Alto Mondego-Alto Zezere scheme in Portugal.

One of the Scottish schemes, of which Sir William gave details, was that known as the Moriston project, which he stated was a combination of the various types of installation in one catchment area. It showed the reservoir type with relatively high-head development, and also the run-of-river schemes lower down. The scheme had main storage in two inter-connecting reservoirs formed from Loch Loyne and Loch Cluanie at the upper end of the catchment, and this gave a highly regulated supply to a generating station at Ceannacroc. It also gave partial regulation for two stations further down the river at Dundreggan and Invermoriston, which have little storage other than pondage to balance the time lag from the upper station. In addition to these main stations, there were two run-of-river stations on tributaries of the main river.

Using this as an example of the way in which hydro-electric development had progressed from the simple isolated station entirely self-contained, Sir William said that in this case controlled water from the upper end of the catchment served three separate generating stations having an aggregate head of about 590 ft., and contributing a long-term average output of about 220 MW.

The second Scottish scheme with which the paper dealt was that of Lochaber, which provided power for an aluminium reduction plant at Fort William. The waters of the River Spean provided all the output required for the initial stages of development, but were insufficient for final demands. The balance was now provided by water from the River Spey, which could not be developed economically in its own basin. This scheme was typical of the latest thought in regard to the overall utilisation of the hydro-electric potentialities of a given district, and typified also the wider outlook of hydro-electric engineers which had been gained over the past century.

The third scheme, the Portuguese scheme, was brought in as a further example since it concerned the work of British engineers carried out abroad. The upper waters of the Zezere were to be developed at Candieria in its own basin and transferred mainly by open aqueduct across the watershed into the Mondego basin to a generating station at Covao da Ponte, where a head of about 400 ft. was available. The combined waters of the upper part of the Mondego catchment and the outfall from the station at Covao da Ponte were to be stored in a reservoir at Assedasse and used at a head of 1,300 ft. at Moreira on the River Zezere. These waters, with the water from the intermediate section of the Zezere, were used again at Valhelhas with a head of 160 ft. Thus every possible exploitation of the potential energy in the rainfall in this area has been made use of by the application of the highest levels of civil engineering skill.

A considerable part of Sir William's paper was devoted to the necessity for the most careful site investigation before the commencement of a hydro-electric project. He noted in some detail the methods

of determining river flows from a study of rainfall records and from river gauging. He said that in a temperate climate rainfall losses caused by evaporation and absorption by vegetation were in the order of about 12 to 14 in. per annum—less than 30 per cent. of the total rainfall. He stated that these figures could be applied with some confidence to rainfall records of preceding years. In tropical climates, however, the losses were much greater, and evaporation was sometimes as high as 92 per cent.

Among other aspects of site investigation was a warning to take note of the different beds which a river may have occupied in the past. With a wide valley there was always the likelihood that old river beds filled with debris could pass unnoticed. This type of formation, continued Sir William, was frequently associated with ancient glaciation and any signs of this, particularly moraines, should be taken as a warning that a buried valley might be present.

He stressed that core borings were essential before making the final choice of a dam site and deciding upon the type of dam to be built. Geophysical methods, in conjunction with borings, were advocated, and in Britain it was usual to employ the resistivity method, which depended upon the differences in electrical conductivity and the proportion of saline solutions in the ground. The resistivity of the ground at various depths was measured by surface observations and, together with information obtained from bore holes, could be used to give a comprehensive picture of the sub-surface structure.

Dealing with future developments, Sir William concluded by saying that very large hydro-electric projects were likely to take place in the near future in Africa and Asia, and these related not only to simple power development but control over the whole river for the benefit of the surrounding countryside and its inhabitants. The flood menace, which many of the world's largest rivers presented to communities living in their lower reaches, could be reduced and could lead to a considerable increase in prosperity.

The growing use of the products of the electro-metallurgical, and electro-chemical industries, such as aluminium, magnesium, artificial fertilisers and calcium carbide, might give the initial impetus to a number of large scale hydro-electric installations.

As an addition to the printed paper, Sir William, in his introductory remarks, also mentioned that the average cost of a hydro-electric installation is now of the order of £60 per kilowatt, and this was closely comparable with recent figures for thermal plants. He also mentioned that hydro-electric engineers, particularly in the North of Scotland, had very largely overcome the objections to the hydro-electric schemes planned by the Board relative to the amenities of the district. A number of pipelines had been placed underground, and by the increased use of tunnelling many unsightly surface works were avoided. Underground hydro-electric construction also tended to safety in time of war, when such installations would be largely immune from aerial bombardment.

Finally, Sir William said that the Severn Barrage which was first promoted 35 years ago, was estimated in the latest report (1944) to produce 2,300 million units per annum at a cost of 0.2d. per kilowatt. The increasing load in Great Britain meant that the Severn Barrage would now only provide—in spite of its very large capacity—some 5 per cent. of the total thermally generated power, and thus its variable output could be absorbed. It would save more than a million tons of coal a year. He thought the day was rapidly approaching when the Servern Barrage would be seriously considered. If construction work started it would greatly enhance the prestige of British civil, mechanical and hydraulic engineers, since it would be one of the greatest works that man has ever undertaken in the world's history.

In a contribution to the discussion, Mr. Hammerland of Sweden said that 97 to 98 per cent. of the energy produced in that country was hydro-electric in origin. He thought that Sir William's paper gave a background to hydro-electric development which in many ways was parallel to that which had occurred in Sweden. He stressed that the Swedish system was now nearly 100 per cent. interconnected, and therefore the maximum operational benefits were obtained. Some 50 miles of tunnel for hydro-electric purposes had been built in Sweden, the longest being 4 miles long. One of the difficulties that had to be overcome by engineers designing Swedish hydro-electric schemes was the necessity to transport large volumes of timber on the Swedish rivers, since this was the method adopted for transporting the timber to the sea.

Mr. Clements of the United States said that he had recently spent a considerable time in Africa investigating various hydro-electric projects. He felt that there was an enormous field in that continent for hydro-electric development on the largest scale, including the multi-purpose developments to which Sir William had referred. The areas covered were so large, and so many different nationalities had a claim on the use of water, that it would be necessary for a very large measure of international agreement to be reached before the fullest benefits could be obtained from many of the most useful African hydro-electric schemes. He stated that the largest scheme of all was the Congo, where the possibilities were tremendous, and he concluded by stating that the hydrological data on which future water power prospects could be assessed was very scanty in many parts of Africa. He hoped that British engineers would use their influence with the various States to make certain that records of river flows, rainfall and the accumulation of similar data were obtained as comprehensively as possible.

Sir William briefly replied to the discussion, in which a number of other speakers took part, and said that he fully endorsed Mr. Clements' plea for greater facilities for the collection of hydrological data, not only in Africa, but also in many other countries.

Cavitation Research. A brochure (No. 12) issued by the Allis-Chalmers Manufacturing Company—one of a series devoted to Current Trends in Power Plant Development—describes some researches on accelerated cavitation phenomena. These researches were conducted by Wm. J. Rheingans of the company's Hydraulic Department and were made by a vibratory type cavitation machine having a variable amplitude and depth of submergence. Tests were made with alkalis, acids and oils as the submerging liquid and the relative resistances of some of the more recently developed alloys were investigated. The results show that accelerated tests can safely be used to indicate the likely behaviour of any material in actual practice.

Fig. 11. View of the d'Enchanet dam (1950) on the Maronne; the power house at the foot of the dam contains a single set operating under a head of 60 metres

The French Hydro-Electrical Industry

PART TWO : A comprehensive account of the evolution and development of the French hydro-electric industry and a forecast of its probable expansion, by PIERRE CHEVRIER and STÉPHANE FERRY, respectively Directeur-Adjoint and Ingénieur en Chef, Service de la Production Hydraulique, Electricité de France.

A CORRECT appraisal of the potential resources of water power in France would require a detailed study, which has not been made, of all rivers and streams. It may, however, be roughly estimated that by 1954, at the completion of the present programme, the total capacity of hydro-electric plants in operation will not much exceed one-third of available resources. The demand for energy will, in all probability, increase in France as everywhere else in the world; the more so as the consumption *per capita* is far from the figures already recorded in other countries, such as Switzerland, Sweden, the U.S. and Great Britain.

An empirical law has sometimes been put forward, according to which consumption doubles in ten years; it is a tempting simplification, but only valid on an average and in favourable economic and political conditions. Assuming that circumstances be such in France as to prove it right during the next 20 years, all available water power would by then be harnessed —provided, of course, that hydro-electricity continued to play the part it now does in the global output.

What, then, are the factors that might influence the future sharing of the task between water power and thermal sources? For many years, before the high-tension transmission network was laid, geography determined the pattern. To-day the two means may compete everywhere in France and it would appear that the simple arithmetics of price cost should decide the pre-eminence of the one over the other. Prices, in fact, are very much of the same order.

It is an uncertain way of reckoning because the facts are too often problematical. In the case of hydraulic plants, for instance, the rate of interest on

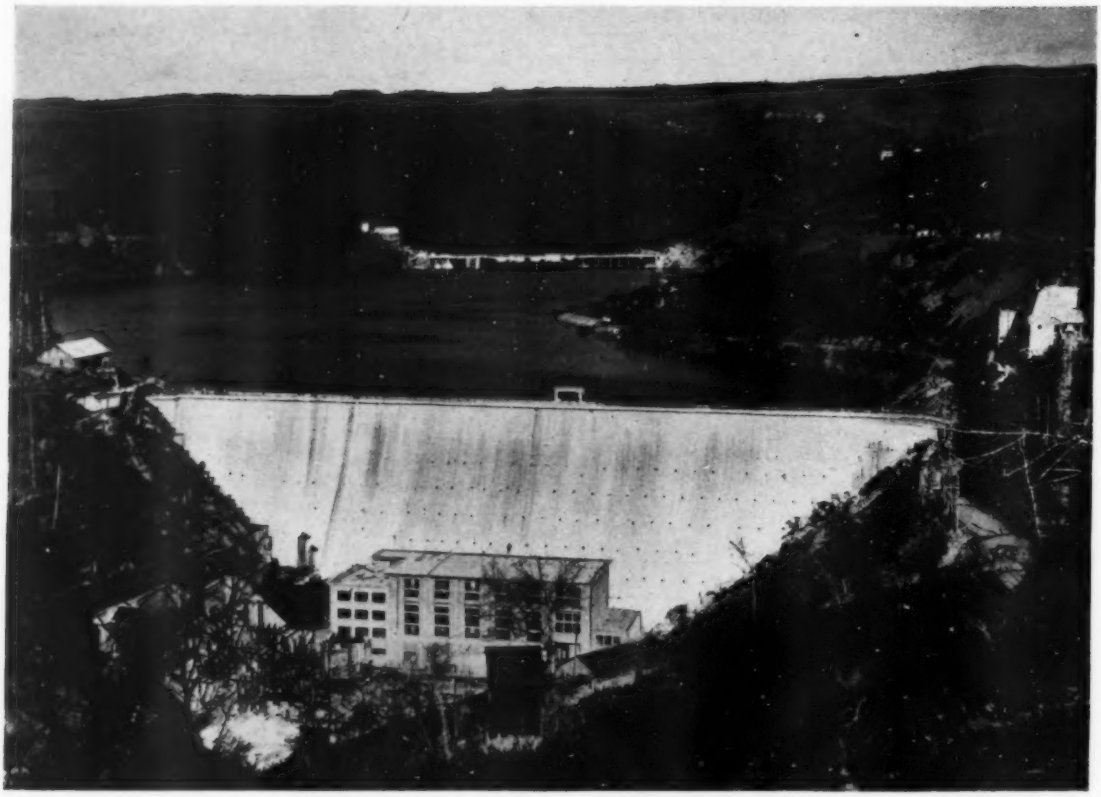

Fig. 12. Castlenow-Lassonte dam and power station on The Lot (1950) containing two 16,000 kW sets, one of 6,000 kW operating under a head of 45 metres. The water storage reserve is 18 million cu. metres.

invested capital is most important; as it now exceeds 7·5 per cent. on long term investments, should that be taken as a basis or should a lower figure be accepted in the hope of later conversions favourable to the borrower? Should it be assumed that, as is now the case, 95 per cent. of the energy theoretically producible will be produced and absorbed, or on the contrary that demand might not exceed 80 per cent. of the available output, as during a long period before 1939? Such comparisons must take into account economic conditions prevailing during the whole life of the installations concerned and cannot be based on the present. Long term economic and even political considerations must supersede arithmetic.

Let us, for instance, follow the trend of thought in France in recent years. Before 1940 water power contributed 50 per cent. of the total output. The "Monnet plan"—1946—sets 60 per cent. as its ultimate aim; the planners were guided by the following considerations.

Natural resources of water power in France are abundant and inexhaustible; the country is not so rich in coal and the seams are running out. In 1946, France, and indeed the whole world, was experiencing a severe shortage of coal and it was felt that thermal development should be restricted to such plants as necessary to burn low-grade fuel, without increasing the consumption of saleable coal (it was even proposed to reduce it at a later stage). In spite of their ideological preference for water power, however, and because of the extreme shortage of energy, the planners had no choice but to exploit to the full all potential sources, taking into account the restrictions imposed on imports. In consequence they included in their programme a certain number of thermal power stations which would burn not only surface coal but also saleable coal. French manufacturers of thermal equipment could not, in any case, satisfy at the time a much higher demand; a long period of unemployment before the war and pillage by the German occupant had considerably reduced the potential of the industry.

What has happened since? In 1947-48, according to these considerations, a supplementary programme of hydraulic equipment, equivalent to 2·5 billion kWh per annum, was embodied in the Monnet plan. (This, coupled with delays due to financial difficulties, has postponed the completion of the works from 1951 to 1953).

In 1949, three unforeseen circumstances led to an altogether different appreciation, at least in what is known as public opinion.

There was no longer a shortage of coal and there were even signs of a buyer's market;

Investment money was as scarce as ever; this was detrimental to water power development, which needs more than twice the capital necessary for an equivalent thermal productivity.

From October, 1948, to October, 1949, an exceptional drought occurred and hydraulic pro-

Fig. 13. Couesque on the Truyere (1950). The reservoir reserve is 20 million cu. metres and the power house is equipped with two 30,000 kW sets operating under a head of 50 metres

duction was lower than ever before; this drew the attention to the problematical character of water power.

In the meantime the French thermal engineering industry had made good progress and was now reckoned to be capable of facing a programme of some 500,000 to 600,000 kW per annum.

These factors led to a strengthening of the thermal development programme, and 800,000 kW of new projects were added to the former 2,100,000 kW of the Monnet plan. This total of 2,900,000 kW would appear to represent an increase of 90 per cent. over the 1946 capacity of 3,290,000 kW, while the comparable figure for water power development would only be 80 per cent. (12 billion kWh of new projects as against a capacity of 15 billion kWh in 1946). This is not so, since some of the new thermal plants will only replace derelict installations which will be closed down.

As a result of these two variations of ideological trend in opposite directions, the relative position of the two rival industries in the final plan is as it was in the original draft —the average contribution of water power being estimated at about 60 per cent. of the total output.

Are there any reasons for thinking that water power will not be able to play in future plans the predominant part it has assumed in the supply of electrical energy in France? The present financial crisis is too artificial for the advantage it gives to thermal investments to be deemed permanent. There remain against water power the suspicions awakened by the prolonged drought of 1948-49. This aspect deserves a detailed study.

In 1948-49 the water power output was below 11 billion kWh; it could have reached 17 billion kWh in normal conditions. The coefficient of downstream producibility[1] was, at 0·61, the lowest recorded during the 28 year period as shown in the following table.

COEFFICIENTS OF DOWN-STREAM PRODUCIBILITY FOR THE WHOLE OF FRANCE

(Hydraulic year from October 1 to September 30)

1921-22	0·92	1935-36	1·31
1922-23	1·01	1936-37	1·02
1923-24	1·06	1937-38	0·89
1924-25	0·85	1938-39	1·01
1925-26	1·09	1939-40	1·15
1926-27	1·13	1940-41	1·18
1927-28	1·04	1941-42	0·88
1928-29	0·91	1942-43	0·86
1929-30	1·12	1943-44	0·82
1930-31	1·23	1944-45	1·06
1931-32	1·05	1945-46	0·86
1932-33	0·86	1946-47	0·81
1933-34	0·92	1947-48	0·91
1934-35	1·04	1948-49	0·61

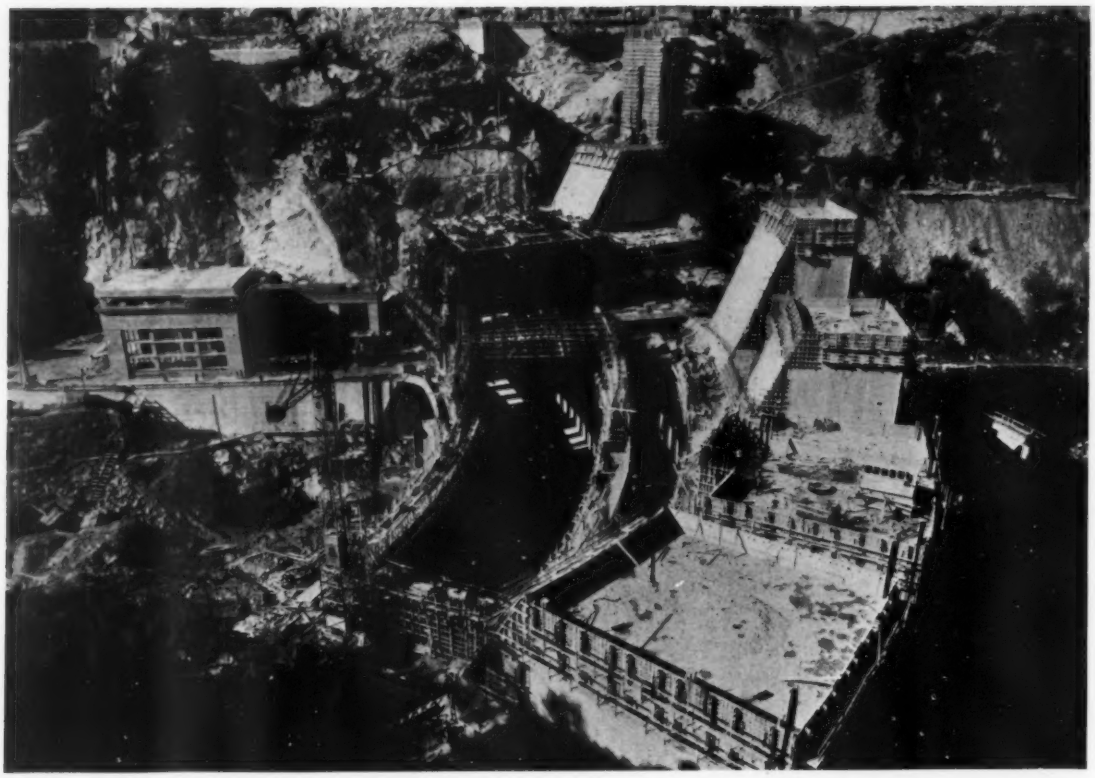

Fig. 14. Chastang dam and power house under construction on the Dordogne. The water reserve is 38 million cu. metres and the power house contains three 15,000 kW sets operating under a head of 70 metres

The anomaly of the 1948-49 year is even more striking if the figure is broken down as between the three main hydrological regions of France:

Alpes - - -	0·80	Massif Central -	0·24
Pyrénées - -	0·57	Whole of France	0·61

The case of the Massif Central is most remarkable.

Thus the supply of hydro-electric energy to the national grid in 1948-49 was short by six billion kWh for a total consumption of 30 billion kWh. It was estimated that consumption was reduced by two to three billion kWh, the rest of the gap being filled by thermal sources.

Indeed, given the available means of production and the demand in 1948-49, there was one chance in two that a supply failure might occur, less grave and prolonged but still imposing temporary restrictions, since the total sum of mean hydraulic winter capacity, stored energy, maximum thermal output and imports could hardly exceed the demand. A security margin of 15 to 20 per cent. might be deemed necessary to minimise the risk of failure; this was the case before 1939 when such a dry winter as that of 1948-49 could have been borne without restrictions. It implies, on the other hand, that a certain amount of water power energy might not be absorbed, even if the thermal output were reduced to a minimum during favourable periods. The magnitude of such waste of water appears in Fig. 15, in which the difference between the available energy and the actual output in any given year represents the sum of the losses through

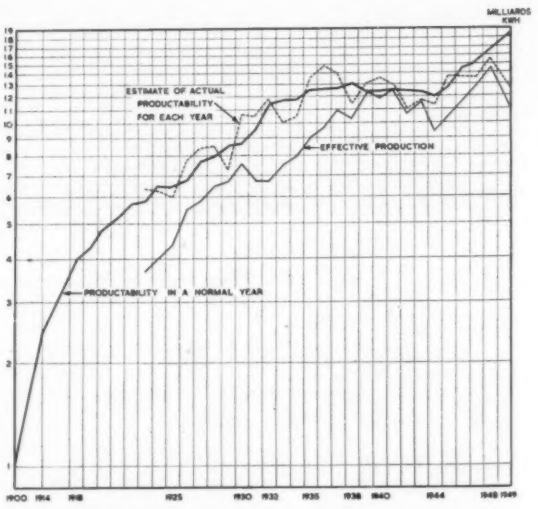

Fig. 15. Variation of production and productability in a normal year (semi-logarithmic scale)

unavailability of equipment and lack of demand.

Apart from the exceptionally severe drought and the inadequacy of the means of production, a fortuitous circumstance contributed to make the situation worse in 1949. As a result of the strike which

Fig. 16. View during constructional stage of the Bort dam and power station on the Dordogne. Here two 90,000 kW sets will be installed to operate under a head of 110 metres. Total water storage amounts to 400 million cu. metres of which 270 cu. metres are utilisable

paralysed the coal mines in October and November 1948, an extra burden had been imposed on the storage water-power stations; the extra output supplied was far higher than would have been prudent to demand, the more so at the time when the drought began to be felt. Thus the reserve of energy went down from 80 per cent. (of maximum capacity) at the end of September to 46 per cent. at the end of November, when it should normally be 70 per cent.; in consequence, load shedding could not be avoided at peak periods for the whole winter.

It is relevant to note that in this case the worsening of the hydro-electric position was due to a failure in thermal supply; this stresses the fact that while water power is dependent upon natural phenomena, thermal means of production are liable to economic and social disturbances.

A convenient proportion and proper use of reservoirs should palliate to a large extent the natural fluctuations of water power. At the completion of the present plan the maximum stored capacity in France will be raised to 3·4 billion kWh—12 per cent. of the mean productivity. The percentage will then be equal to that now recorded in Switzerland and Italy, countries which do not enjoy thermal means of regulation.

Thus it appears that the natural irregularity pertaining to hydraulic power should not be a handicap to its development in France. A production system calling for two-thirds of water power and one-third

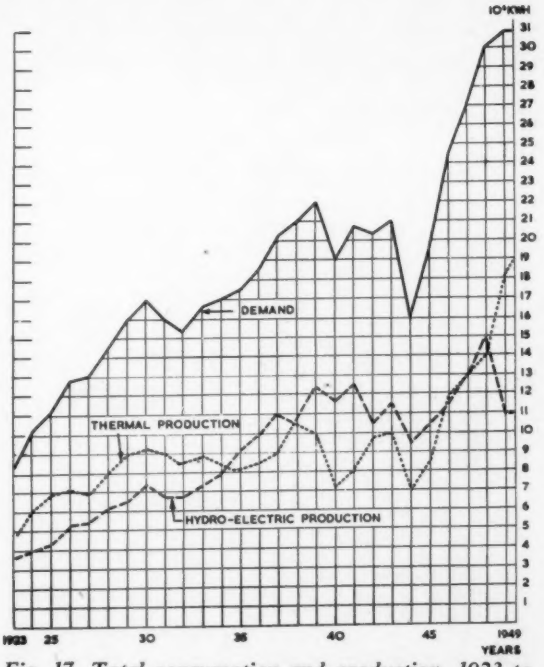

Fig. 17. Total consumption and production, 1923 to 1949

Fig. 18. Another view of the Bort project under construction, showing the pipelines

of thermal power in a mean year seems perfectly acceptable, provided that the margin between (Mean hydraulic winter capacity + Reservoirs + Maximum thermal) and winter demand be wide enough; and also that it be possible to maintain in the future a reasonable percentage of reservoir-stored energy. In the next few years, after the completion of the Monnet plan, it will not be difficult to maintain such a proportion in new projects since several very large reservoirs are already under consideration.

Among them are:—

Champagny (Basin of the Doron de Bozel, a tributary of l'Isere) - -	Reserve 300 million kWh
Mont-Cenis (Basin of l'Arc)	Reserve 400 to 500 m. kWh
Serre-Poncon (Basin of the Durance) - - -	Reserve 235 million kWh
Granval (Basin of the Truyere) - - -	Reserve 200 million kWh

The question arises whether from the point of view of cost-price water power will be able to compete with thermal power in the future: it may be thought, for instance, that the best natural sites have been used first and that less satisfactory conditions will have to be met. On the other hand, the efficiency of thermal machinery has considerably increased through the continued improvement of the thermodynamic cycle (pressure and, even more, temperature). Fortunately, these unfavourable factors are balanced by others.

Earlier projects did not always exploit such favourable water falls as Sarrans and Brommat on the Truyere, or those on the Romanche. It remains true, however, that falls in less propitious conditions will have to be equipped in the future; others will benefit from the creation of regulating reservoirs. The falls of Cordeac (already harnessed), St. Pierre Cognet and Monteynard, on the Drac, are cases in point; they derive much of their value from the reservoir of Le Sautet. The fall of Couesque, where work is in progress, below the reservoir of Sarrans on the Truyere, is another example. Conversely, such reservoirs will be worth building when the harnessed fall becomes adequate through the erection of more plant downstream.[2]

It may also be mentioned that while unexploited falls are largely low falls, particularly on the Rhine, the Rhone, the Isere, the Durance, etc., it is precisely in this field that hydraulic construction has most progressed with the development of Kaplan turbines and the improvement that has been made in mobile dams.

Civil engineering is responsible for the greater part of the cost of hydro-electric equipment. Great progress has been made within recent years in carrying out work of this kind. The cost has been reduced, and in particular it has been possible to improve the general design of these projects by freeing the engineer from some of those natural limitations which have hitherto restricted him.

It is for such reasons that certain localities favourable for the harnessing of big reservoirs could not be developed hitherto.

The cost of a loaded dam, with 460·000 m^3 of concrete, at Granval, on the Truyere, was prohibitive before the war; to-day the technique of multiple vaults reduces the necessary volume of concrete to 225·000 m^3 and the project becomes feasible.

The barrage of Castillon—100 m. high—on the Verdon could not have been erected without the modern technique of injections which has made it possible to consolidate and make water-tight the

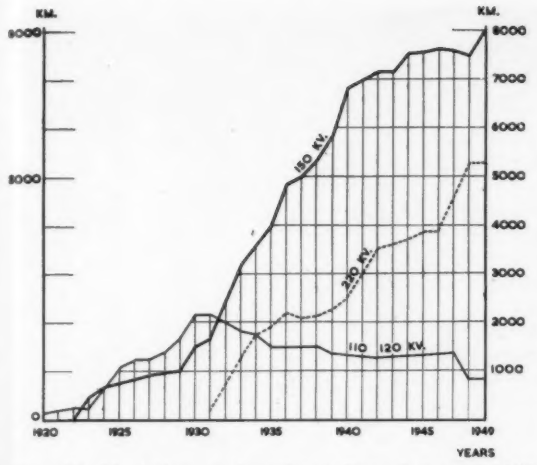

Fig. 19. Variation in length of lines between 1920 and 1949

fractured and cracked calcareous rock which supports it on the right bank. For the last 50 years the attention of engineers has been drawn to the site of Serre-Poncon, on the Durance, for a reservoir, on account of the considerable advantages which would derive in the electrical and agricultural fields from the regulation of the Durance; but it is only to-day that the erection of a dam in the river bed becomes a reasonable proposition.

Further, tunnels are sometimes placed under a head of more than 100 m. whereas ten years ago engineers did not exceed 30 m. This, together with the increase in capacity of individual units, has made it possible to develop in a single station waters that previously had to be exploited by scattering the generating plant over a series of stations.

This ability to develop a head by means of a single station has contributed to the better utilisation of the upper reaches of the catchment areas, by the systematic use of multiple aqueducts and sometimes by auxiliary pumping. In the same way, large reservoirs are often fed by diverting or pumping water from neighbouring basins, the additions themselves sometimes representing a drainage greater than that derived from the natural catchment area. These various advances in conception have made it possible to use sites that have hitherto not appeared susceptible to economic development.

There are many low power falls among those to be harnessed and the cost of their exploitation would be prohibitive if a permanent watch were to be kept in plants according to former practice. This is no longer necessary thanks to the technique of automatic control[3] and the cost of exploitation can be lowered to an acceptable level.

It would thus appear that hydraulic techniques and the conception of projects in recent years show very important progress so that in the future water power will be able to compete in cost with thermal sources.

General Conclusion

French water power is important and varied as it springs from three principal mountain ranges: the Alps, the Pyrénées and the Massif Central.

This diversity of natural conditions is reflected in the projects which have derived their permanent character from their immediate surroundings.

Thus the Massif Central, furrowed with deep granitic gorges, is ideal for barrages where the fall is created without headrace and which at the same time dam an important reserve of water. The harnessing of the Dordogne offers a very characteristic example (see Fig. 20). In the sharp relief of the Pyrénées supply basins are smaller and the flow less under very high head; natural high-altitude lakes, the level of which is sometimes slightly raised by damming, constitute reservoirs of high energy value. In the Alpes the types of installation are very diverse varying with the head of fall, the length of penstocks, the nature of reservoirs and the importance of supply basins. Low-head plants are to be found on the lower waters of great alpine streams and on the main rivers.

The technical progress which has permitted the construction of more and more powerful units has led to more complex and centralised projects which, however, keep the individuality imposed on them by nature.

As we have seen, the problem of French water power has been treated as a whole. The unity has been achieved by interconnection.

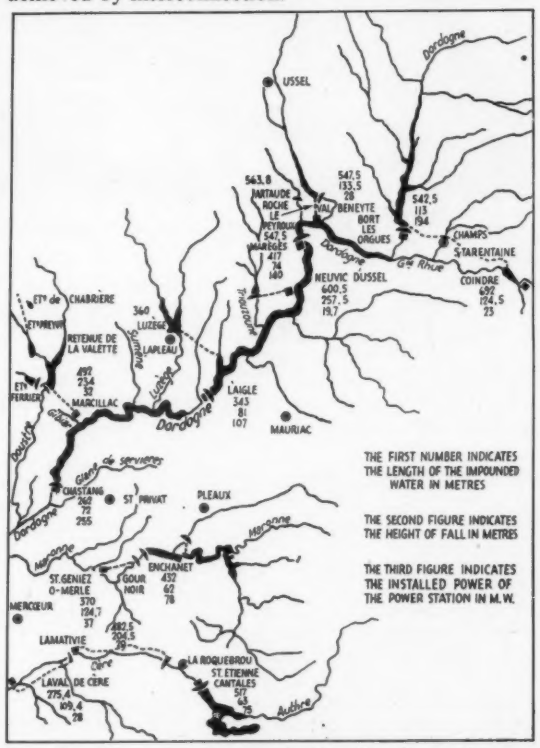

Fig. 20. Diagram showing hydro-electric equipment in the Dordogne

The present analysis has shown nothing unfavourable to the development of water power which, according to perceptible prospects, should maintain its preponderance over thermic sources—at least for as long as potential hydraulic resources remain available.

Although the evaluation of French total resources is difficult and, in part, arbitrary, it may be estimated that they will all be harnessed within one generation.

Consequently, great care is taken not to sacrifice

(Concluded on page 272)

Fig. 1. Hungry Horse dam site; general view of right abutment and channel system

The Construction of Concrete Dams

By ELMO C. HIGGINSON, Materials Engineer, Office of the Chief Engineer, United States Department of the Interior, Bureau of Reclamation, Denver, Colorado. A consideration of materials and their specifications.

THE construction of large concrete dams is an undertaking that challenges the very best in human endeavour. They must fulfil the requirements of economy, durability, impermeability, and safety. Although the construction of these massive structures is usually influenced by economic considerations, once they are completed the dams greatly influence the safety of a large group of people; in fact, the failure of certain new concrete dams might actually cause loss of life or property affecting a million or more individuals. Consequently, to insure the safety and effectiveness of these structures for a long period, the selection of the materials and the control of the manufacturing processes entering into their construction are both involved and technical. Since they can be no better than the materials from which dams are made, the selection of the materials for concrete are of foremost importance.

Information in this article is based on laboratory and field experience in the United States Department of the Interior, Bureau of Reclamation, the organisation responsible for the Hoover, Grand Coulee, and Shasta Dams.

Concrete Aggregate

Since aggregates constitute at least 75 per cent. of the bulk of concrete, economical considerations demand that acceptable material closest to the sites be selected. In addition to the prime consideration of quality, criteria which affect this selection are: ownership of the deposit, grading, ground water conditions, overburden, costs, and quantity available. Further, if rock from a quarry is being considered in the absence of, or in competition with, a natural sand and gravel deposit, an additional consideration is the manner in which the rock breaks into smaller sizes with con-

Fig. 2. View of rock ladders for 3 in. and 6 in. maximum gravel; the purpose of this structure is to minimise breakage by limiting the total fall to short steps

ventional crushing equipment. That is, do the particles appear flat and slabby, or do they approach spheres or cubes? The investigating engineer must recognise the fact that, even though aggregates are similar in particle shape and have identical gradings, their concrete-making properties may vary widely. Another important consideration in choosing between two or more otherwise acceptable aggregates, is that of water requirement, which, in turn, affects the cement requirement.

Service records and laboratory investigations comprise the two general methods for determining the quality of aggregates. Each method supplements the other and neither is 100 per cent. reliable. Furthermore, a combination of the two is not infallible. Of prime importance in the evaluation of service records is the fact that a concrete structure made with aggregate proposed for use in a dam may be in poor condition after a few years of service, even though the aggregate is of first-class quality. This paradox may be caused by poor cement, lack of cement, alkali-aggregate reaction, or by inferior construction techniques. Conversely, a structure that has withstood the ravages of time lends enough credence to warrant the selection of concrete aggregates from the same source for a future dam. This same principle would, of course, apply in some respects to the selection of other construction materials. However, large concrete dams in the United States are seldom constructed near a concrete aggregate deposit previously provided with a good service record. Therefore, laboratory investigations play a very prominent rôle in the determination of quality aggregates.

Among those necessary routine laboratory tests, well-known throughout the engineering world, are: specific gravity, absorption, sodium sulphate soundness, organic impurities, and Los Angeles abrasion. Recently, petrographic examination, freezing and thawing, wetting and drying, thermal and volume-change studies have been contributing considerably to the selection of the best concrete aggregate. Petrographic examination is particularly valuable in detecting materials which react with alkalies (Na_2O and K_2O) in Portland cement to cause expansion, cracking and deterioration. Opal (amorphous hydrous silica) is the most reactive aggregate material known; in fact, it is so reactive, in some cases, that small amounts of opaline silica present in aggregates which were otherwise unobjectionable, have actually caused excessive expansion and rapid deterioration of the concrete. Other aggregates which must be viewed with suspicion are fine-grained igneous rocks ranging from rhyolitic to andesitic composition. The petrographic examination is also a valuable research tool in classifying each sample according to the mineral types. Consequently, by an analysis of the types of aggregate embedded therein, the future behaviour of a concrete dam can now be forecast with some certainty, provided the cement is satisfactory.

Accelerating weathering tests, such as freezing and thawing and wetting and drying, can be made on concrete containing the proposed materials. Although

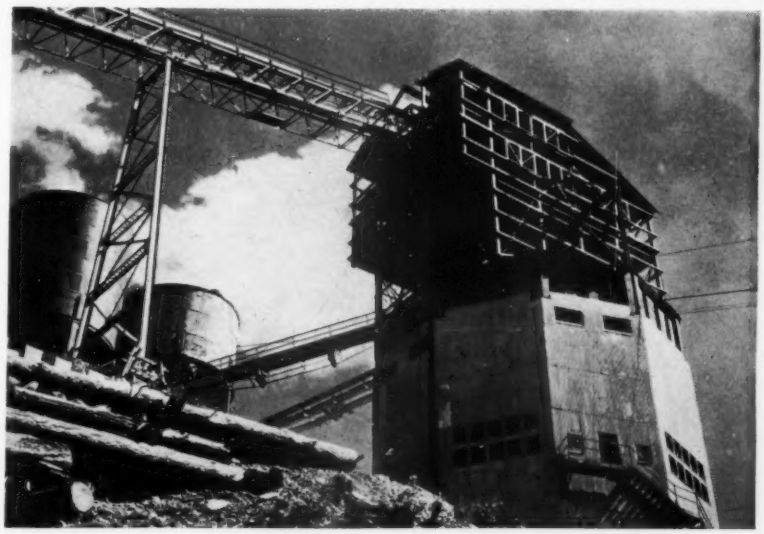

Fig. 3. Hungry Horse dam; concrete mixing plant and storage silos for cement and pozzolan

no standard procedure has been devised for these tests, it is evident that equipment, automatic both in operation and control, are requisites to reliable test results. The automatic feature is important to eliminate human errors of operation. These tests are particularly valuable because they closely simulate the weathering processes of nature, and permit actual " trial runs " of concrete prior to field use.

Because of the large dimensions and rapid rates of construction of most concrete dams, a major problem is the prevention or removal of excess heat in the concrete. Consequently, laboratory investigations of the thermal properties of a concrete and its ingredients are prime requisites to intelligent design and selection of those ingredients.

The grading and quality determinations of an aggregated deposit can best be made in the field during test-pitting operations. Aggregates up to 6-inch diameter are used where available to save cement, thereby reducing both cost and the amount of heat generated. All information obtained in the field should be furnished to the laboratory so that a complete analysis of the aggregate problem can be intelligently made. The final decision on an aggregate source should be made in a joint conference of construction, design, and laboratory engineers.

Portland Cement

Although Portland cement is the most influential and costly material in concrete, construction engineers usually have less control over the quality of the cement than they do over any other concrete ingredient. In a co-operative effort to improve the quality control of cement, consumers and manufacturers have written specifications for five types of Portland cement, and these are now recognised by the American Society for Testing Materials, and the United States Government. Although this is one of the most progressive steps taken in recent years in the development of Portland cement, increased knowledge and experience will undoubtedly change and improve cement specifications.

Low heat and modified types of cement are used most in dam construction because of the heat-generating characteristics of these cements. The typical compound composition for these two types of cement are given in Table I.

Where reactive aggregates must be used, a limiting value of 0·60 per cent. total alkalies (Na_2O and K_2O) is imposed in the cement specifications.

TABLE I

Type of cement		Compound composition, percentage							Ignition loss	Number Averaged
		C_3S	C_2S	C_3A	C_4AF	$CaSO_4$	Free CaO	MgO		
Modified	Max.	55	39	8	16	3·4	1·8	4·4	2·0	
	Min.	37	19	4	6	2·1	0·1	1·5	0·5	
	Avg.	46	29	6	12	2·8	0·6	3·0	1·0	28
Low heat	Max.	44	57	7	18	3·5	0·9	4·1	1·9	
	Min.	21	34	3	6	2·6	0·0	1·0	0·6	
	Avg.	30	46	5	13	2·9	0·3	2·7	1·0	16

Fig. 4. Clearing aggregate deposit and reservoir area one mile upstream from Hungry Horse dam site. Aggregate area in foreground

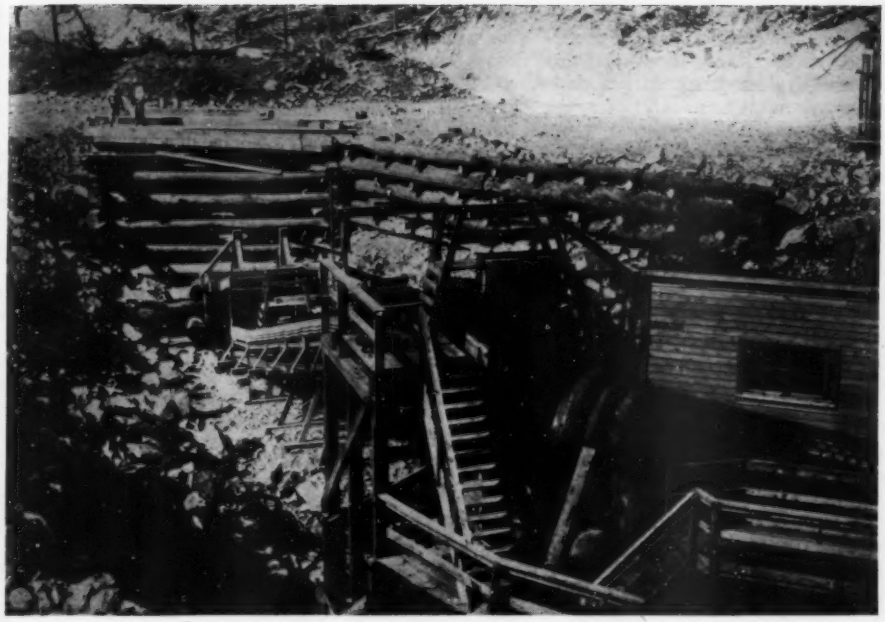

Fig. 5. General view showing truck - unloading dock and portion of primary screening and crushing plant, Hungry Horse dam

Fig. 6 (below). Diversion tunnel Hungry Horse; view inside pilot tunnel

Admixtures

Most prominent among admixtures used in concrete construction are air-entraining agents. Correct amounts of these agents improve the workability of the mix, reduce the water requirement for a given slump, reduce bleeding, reduce permeability, improve sulphate resistance, and increase the durability of concrete by amounts up to 800 per cent. as measured by freezing and thawing tests. In mass concrete, entrained air is particularly desirable because it permits a reduction in the cement content with an attendant reduction in temperature rise. Air entrained in richer mixes does cause a slight reduction in strength; however, laboratory tests reveal that air entrainment in lean mixes (two or three sacks of cement per cubic yard) in small amounts actually increases the strength. Consequently, these lean air-entrained mixes are being used in the interior of some gravity-type dams where the stresses are very low. In general, those agents which are produced as a byproduct are found to be the least expensive. Since air entrainment is comparatively new, and because of the fact that many organic compounds have the ability to entrain air in concrete, the method of selection of the cheapest agent has not been standardised. At this time, therefore, actual use of agents, coupled with laboratory tests and trial mixes, affords the best known method of selection of an air-entraining agent. Calcium chloride, which is foremost among the various other admixtures employed in the manufacture of concrete, is used to increase the early strength of the concrete essential to expedite form removal.

Selection of admixtures for other purposes should only be made from laboratory tests with the materials to be used on a specific job.

Pozzolans

Pozzolans are now being used in a number of major concrete structures to combat alkali-aggregate

reaction, to reduce both cement cost and temperature rise, and to increase workability. The use of pozzolans, particularly in combination with modified Portland cement, also reduces drying shrinkage and thermal shrinkage, and improves extensibility or crack resistance.

A pozzolan is any siliceous material, natural or artificial, which, in the presence of lime and water, develops cementitious properties. Their use is not new, as the Romans used pozzolanic cements 2,000 years ago. Materials used as pozzolan fall into the following groups :

1. Clays and shale which must be calcined to activate.
2. Opaline materials which may or may not require calcination.
3. Volcanic tuffs and pumicites.
4. Industrial byproducts such as blast furnace slag and fly ash.

Because comparatively few sources of pozzolanic materials are known, their use in mass concrete has been somewhat limited. However, the increasing interest in Portland-pozzolan cement for massive construction is increasing the interest of the cement industry in the mill production of such cements. When finished Portland-pozzolan cements do become generally available, the necessity of handling a separate material at the job will be obviated and the production of uniform mass concrete should be greatly facilitated. Meanwhile, laboratory research should definitely supplement the selection and use of pozzolanic materials in concrete.

To date, the Bureau of Reclamation has used, or is using, pozzolans in four major structures, as follows :

1. Pumicite in Friant and Altus Dams to save cement and reduce generated heat.
2. Monterey shale in Davis Dam to counteract alkali-aggregate reaction.
3. Fly ash now being used in Hungry Horse dam, a gravity-arch structure which will contain three million cubic yards of concrete when completed, to save cement and reduce generated heat.

In general, mixing water should be free from excessive amounts of alkali and other chemical impurities. Where the quality is questioned, chemical analysis should be made.

Designing the Mix

The design of a concrete mix is actually the determination of the most economical and practical combination of aggregates, cement, water, and in some cases, admixtures of pozzolans that will produce a mixture having the desired degree of workability and the ability to develop the required qualities on hardening. The final selection of all of the ingredients in concrete should be proved by designing and making laboratory trial mixes, together with complete laboratory tests for strength, durability, thermal properties, modulus of elasticity, volume change, permeability, and others. Essential steps in designing mix are :

1. Select the desired percentage of entrained air, and the amount of agent required to entrain it.
2. Select the water-cement ratio, bearing in mind the advantage of low water-cement ratio from the standpoint of durability, strength, and economy. (Some engineers select the amount of cement per unit volume, instead of the water-cement ratio.)
3. Select the limits of slump and estimate the amount of water per unit volume required to produce this slump.
4. Determine the largest size of available aggregate suitable for the concrete.
5. Estimate the percentage of sand which will give the required degree of workability.
6. Finally, compute trial mix proportions, mix, and make adjustments.

Summary

Construction of massive concrete dam structures in the U.S. warrants expert consideration in the selection of not only the type of structure and its site, but also of the aggregates, cement, admixtures, pozzolans, mix water, and finally of the proper proportions of the ingredients themselves.

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1. Title No. 46-6—" The Use of Portland-Pozzolan Cement by the Bureau of Reclamation " by R. F. Blanks, Volume 21, October 1949, No. 2, American Concrete Institute, New Center Building, Detroit 2, Michigan.
2. " Cracking and Temperature Control in Mass Concrete " by C. Rawhouser, Volume 16, No. 4, February 1945. American Concrete Institute, New Center Building, Detroit 2, Michigan.
3. " Practices, Experiences and Tests with Air-Entraining Agents in Making Durable Concrete " by R. F. Blanks and W. A. Cordon, Title No. 45-25, February 1949. American Concrete Institute, New Center Building, Detroit 2, Michigan.
4. Special Technical Publication No. 83—"Grading of Mineral Aggregates for Portland-Cement Concrete and Mortars " by W. H. Price, 1948, American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.
5. Reprint from Volume 48, 1948—" Tests Used by the Bureau of Reclamation for Identifying Reactive Concrete Aggregates " by R. C. Mielenz and L. P. Witte, American Society for Testing Materials.

(Continued from page 267)

lightly resources of doubtful present value but which may, in the near future, become precious. On the other hand, Electricite de France has already put under study the exploitation of other natural sources of energy such as tidal power (see WATER POWER, January-February 1950) and wind power.

REFERENCES :

(1) The coefficient of down-stream producibility for a given year is the ratio of the output producible during this given year by all down-stream plants in full working order to the average annual output which could have been produced by the plants in similar conditions during the whole period of reference. In the above table this is from October 1, 1921, to September 30, 1949.

(2) There are three plants on l'Eau d'Olle, a tributary of the Romanche; le Rivier le Vernay and la Fonderie d'Allemont. The falls (total drop 817m.) are partially equipped and they are regularized by the Bramant lake (2 million m^3 – 2447m. alt. The height of the dam could easily be raised so as to increase the capacity of the lake by 2 million m^3, equivalent to an extra 1,6m. kWh of winter output for the three plants in question. It would not have paid the Société Electrique de l'Eau d'Olle to carry out the work.

Since the nationalisation, all the falls on the lower Romanche, and on l'Isère (total drop 475m) have come within the province of *Electricite de France*, together with the above mentioned falls on l'Eau d'Olle. The raising of the Bramant lake dam is now worth undertaking since the extra 2 million m^3 of water stored will produce, besides 1,6 million kWh on l'Eau d'Olle, 1 million kWh on the Romanche and l'Isère.

(3) Automatic control is normally economical for generating stations equipped with one or two sets. It is very popular in new installations in France in the following forms:

(a) Remote control from another station is only worth while if these are not too far apart. It enables a complete absence of personnel in the controlled station except for periodic servicing and cleaning.

(b) Complete automatic operation through remote control of the machinery from the upstream level of the water intake is justified in the case of small stations (less than 10 million kWh per annum) if it also enables complete absence of permanent supervision.

(c) Semi-automatic control calls for safety devices to stop the sets in case of accident and complete centralization of control. It is then only necessary to house one watchman near the plant, with an alarm system in case of need. This is the solution preferred by *l'Electricite de France*.

Marion Excavators to be manufactured in Great Britain

A LICENCE recently granted to John Blackwood Hodge & Co. Ltd. by the Marion Power Shovel Co., of Marion, Ohio, will permit the manufacture of Marions in the United Kingdom, commencing immediately. A full range of models will eventually be manufactured in this country, but production is

starting immediately with the 111-M 3½-4 cu. yard model, and delivery of the first machines is expected in about 18 months' time. Distington Engineering Co. Ltd., of Workington (subsidiary of The United Steel Companies Limited) have been appointed by the Blackwood Hodge Organisation, under a long-term agreement, to manufacture the range of models, with the full approval of the American manufacturers, the Marion Power Shovel Co.

The manufacture of these excavators in Britain will enable users throughout the sterling area to buy a full range of excavators, draglines and cranes for sterling—an enterprise which will be of benefit in saving dollars. The Blackwood Hodge Organisation will be responsible for the distribution and servicing of the Marions in Britain, India, and many territories in Europe, Africa and Asia.

Holman "Dryductor"

Although all dusts from drilling operations are not highly inimical to health they are objectionable and even the most innocuous varieties constitute an unpleasant nuisance. Hitherto water has been used as a suppressant but, of course, introduces a further source of nuisance, particularly in hot workings where the spray is apt to take up heat and engender an atmosphere which becomes more and more uncomfortable as it approaches saturation point.

After some six years of experimental effort, Holman Bros. Ltd. have succeeded in producing a completely dustless rock drill, the "Dryductor," which extracts the dust as it is formed in the hole and ejects it into a cyclone separator, a bag filter or a combination of both. With a cyclone separator close by the drilling equipment, it is claimed that up to 95 per cent. of the dust can be trapped, leaving the remainder to be collected in some type of filter further outbye. Or if the dust is highly dangerous it can be led by means of a pipe to some point where it can be effectively trapped or taken to the open atmosphere. As this pipe is under vacuum there is no danger of fine and dangerous dusts escaping into the working atmosphere. The vacuum is provided by a suction fan which may be situated almost any distance away, and a point of practical importance is that the drill cannot be started unless the suction is in operation.

As will be gathered from the accompanying diagram (Fig. 1), the drill is traversed longitudinally by a tube of relatively large diameter and the hole through the drill steel is very much larger in diameter than that used for wet drilling. The communication with the hose pipe is in direct line with the centre tube so that no pressure loss is incurred by eddying. Fig. 3 shows a diagrammatic arrangement of the

Fig. 2. "Dryductor" mounted on an Airleg

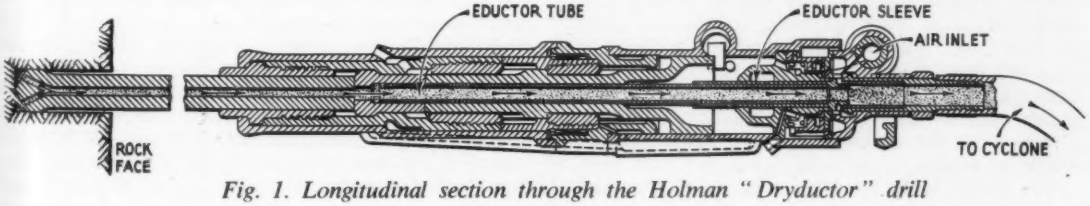


Fig. 1. Longitudinal section through the Holman "Dryductor" drill

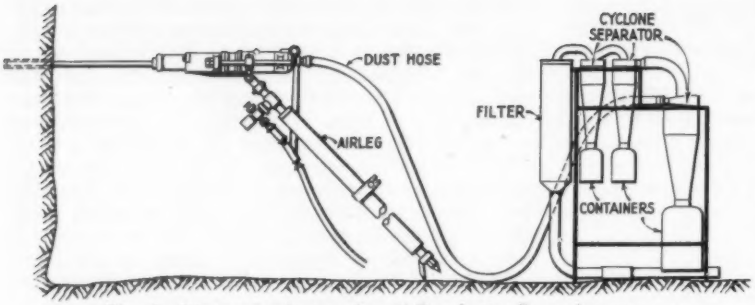


Fig. 3. Diagram of complete "Dryductor" equipment

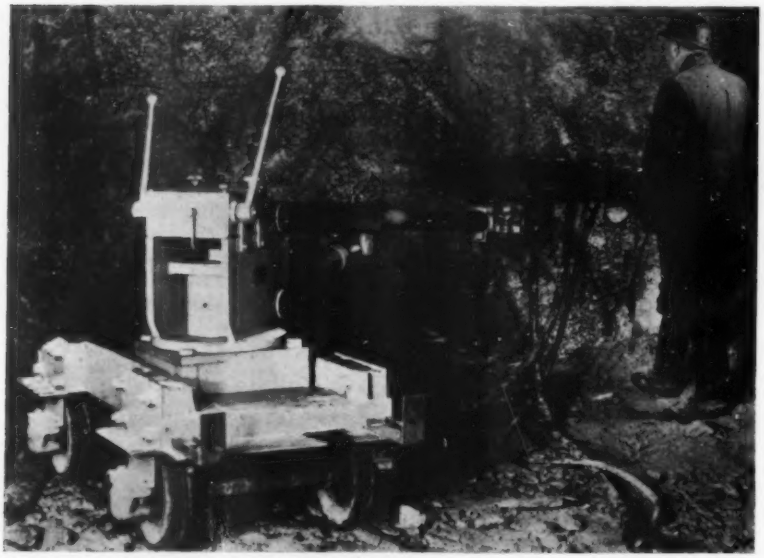


Fig. 4. "Dryductor" mounted on hydraulic Drilrig

complete equipment, apart from the suction fan, with the drill mounted in conjunction with a Holman Airleg attachment, and the two photographic reproductions show the dustless conditions which are obtained with the "Dryductor" in operation. The final picture, Fig. 4, shows the "Dryductor" mounted on a Holman hydraulic Drilrig.

Fiat Industrial Crawler Tractor

Mackay Industrial Equipment Limited have been appointed sole British concessionaires for Fiat industrial crawler tractors, and it is hoped that such an arrangement will help to reduce this country's dollar expenditure on earth-moving equipment. The tractor is made by Fiat, in Turin, Italy, a firm with a well established reputation in automobile manufacture. It is intended for heavy industrial use such as earth moving on civil engineering contracts. Provision is made for fitting a bulldozer (a hydraulically operated Bray type has been fitted to the demonstration model) and a trailing scraper. In addition, a belt pulley may be fitted to drive stationary equipment, a rope winch for hauling, or a power-control unit for operating trailed equipment.

The engine is the four-stroke Saurer type manufactured under licence by Fiat. In this engine an effort is made to increase the air turbulence; in addition to fitting masked inlet valves capable of imparting a whirling motion to the air, the piston crowns incorporate shaped combustion chambers which produce further turbulence. This and other refinements, it is claimed, reduce fuel consumption by approximately 20 per cent. and increase thermal efficiency by 33⅓ per cent. The exhaust valves are push-rod operated, and for fuel injection a Bosch-type pump and Saurer injectors are used. We understand that the injectors are of a design that obviate incorrect assembly. A two-cylinder, 10 h.p. auxiliary petrol engine is used for starting and it is pointed out that such an arrangement permits the full working pressure of lubricating oil in the main engine to be built up before starting. A gear-type pump forces lubrication to the engine, and to ensure priming even when working on most unfavourable transverse or longitudinal gradients an auxiliary scavenging pump is provided.

The master clutch runs dry and is of the single-disc type; five forward speeds and one reverse speed are provided, and all gears are located by a visible and clearly marked gate. The transmission system is housed in a heavy cast-iron casing to ensure good shaft alignment on any gradient. Heavy-duty ball-bearings carry the gear shafts.

Although the more usual method of steering may be provided if desired, wheel steering is standard. This does not involve the use of differential gear as used in an automobile but is actuated through multi-disc clutches on to the respective tractor drives. By this method, the makers contend, manoeuvrability is improved and support is given to the operator when travelling over very uneven ground so that he is better able to steer the machine along a straight path to avoid sudden load fluctuations which tend to shorten the life of any transmission system.

The track frames are fully oscillating and an "A" type anchorage is used at the rear end to ensure maximum stability. Two heavy-duty transverse leaf springs are provided and they are anchored at their centres and supported by hardened steel rollers at their outer ends. All support rollers, track wheels, and front idlers are fitted with roller bearings protected by felt dirt-excluding seals.

The tracks are of the articulated link type with pin and bush joints. Standard track shoes are 17¾ in. wide and give a ground pressure of 4.55 lb. per sq. in., but for work on particularly soft ground 25½ in. shoes

may be fitted to reduce the pressure to 2.84 lb. per sq. in. Induction hardening has been used to extend the life of these parts. For road work, street plates of an ingenious clip-on design can be fitted—it requiring less than one hour to change two complete sets of plates.

Electric lighting is fitted as standard there being two forward and one rear-facing floodlights to give adequate illumination for night work; a red rear light is also fitted.

The horse-power available at the drawbar is 38 and at the belt pulley 45, and the total weight of the tractor is 10,890 lb. At the rated engine speed, a speed of 1.4 m.p.h. is obtained when in first gear; 2.24 m.p.h. in second; 2.8 in third; 3.5 in fourth; 5.28 in fifth; and in reverse, 1.7 m.p.h. The maximum drawbar pull is 10,670 lb.

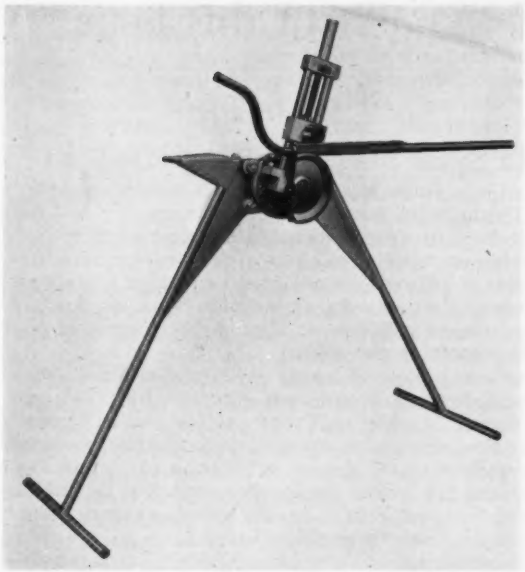
Throughout the design attention has evidently been paid to a number of details likely to improve performance and reduce maintenance and running costs. For instance, the lubricating oil is screened in an edge-type metal oil filter, and to ensure that the filter is cleaned frequently, and to avoid the human element, each operation of the master clutch rotates the filter plates. Moreover, the air-filter hood extension which has to be removed when working the petrol-driven starting engine is fitted with a spring-loaded fastener capable of easy replacement, so that there is less likelihood of the operator omitting to replace the cap when running the diesel engine.

An ample stock of spares will be kept by Mackay Industrial Equipment Limited, and as in the case of all machines supplied through this firm, their service-exchange scheme will operate. Under this scheme a reconditioned engine is exchanged on site for an engine requiring overhaul so that each tractor may be kept working for the maximum number of hours. In addition, users of Fiat tractors may have the use of the Mackay quarterly inspection service whereby each machine is inspected at three-monthly intervals by specialist maintenance engineers who furnish an independent report on the condition of the machine.

Hand-bending Machine

THE "Truset" hand bending machine manufactured by Chamberlain Industries Ltd. is the latest of the "Staffa" range of equipment and is the direct result of a demand for a low-cost machine capable of giving close-set precision bends. It consists of two main components—the base and bending arm—the former being circular and carrying lugs suitable for universal mounting on either a bench, vice, or bending stand. Equispaced around the base are holes for a stop-pin, which, when used in conjunction with an additional stop screw on the bending arm, allows infinite adjustment to any angle of bend position for repetition work. The bending arm, rotating about a centre-pin fitted to the base, consists of two bars of high-tensile steel carrying an infinitely adjustable bending pin, fitted into the head block at one end, and the handle block at the other. A feature of the machine is the pin which restricts the movement of the bending arm and automatically ensures a correct angle of lead—a factor of the utmost importance when bending copper and light gauge tubing.

A light steel fabricated bending stand can also be supplied, as shown in the accompanying illustration;



although light and neat in appearance it is stated to be capable of withstanding severe usage. The principle of this stand is that it becomes complete only when fitted to the machine, eliminating any unnecessarily large locating plates, and when dismantled, becomes merely two tubular legs of extreme portability.

A small pipe vice can also be supplied for convenient mounting on the stand. The tube formers, which are readily fitted to the machine, carry their own back-stops, ensuring effective gripping of the tube and distortion-free bends. With the use of these formers any tube sizes up to a maximum of $\frac{3}{4}$ in. diameter in gas tube and $1\frac{1}{2}$ in. diameter in copper and light-gauge tube can be handled cold and unloaded. The design of both the machine and the formers enables rapid and efficient left and right hand bending through any angle up to 180 deg. to be effected (after allowing for spring in material) with the minimum of straight adjoining the bend.

Carlisle Graders

Carlisle motor graders are now being produced in Great Britain, and will be available throughout the sterling area through the Blackwood Hodge Organisation. They are being built by Distington Engineering Co. Ltd. (a subsidiary of The United Steel Companies Ltd.) and John Blackwood Hodge & Co. Ltd. and their oversea subsidiaries are offering complete after sales service for the graders in all parts of the world. The Model 200 grader has a blade constructed entirely of "FIRTHAG" wear-resisting steel and measuring 12 ft. x $24\frac{1}{2}$ in. x $\frac{3}{4}$ in.; it is capable of exerting a maximum blade pressure of 13,310 lb. and is fully hydraulic in operation.

Holman Bros. Ltd. A series of publications received from this firm relate to Rock Drills (General Information); Holbits; Drifters, Sinkers and Stopers; the Handril-Birleg-Holbit Combination; Tube Expander Motors; the Rotogrind; and an Abridged List of Holman Products.

Digest of this Issue

Sommaire

La houille Blanche en Finlande (page 244).

Cette étude très compléte des ressources hydro-électriques du pays montre que les réserves potentielles de la Finlande méridionale sont presque entièrement misés en valeur. Ainsi les sociétés d'exploitation sont-elles de plus en plus amenées à envisager le transport à longue distance depuis la région Nord, et, plus tard, un emploi croissant de la puissance thermique pour la production d'électricité.

Onze projets nouveaux et l'extension d'une station existante ont été entrepris entre 1940 et 1946. Les travaux de génie civil sont pour la plupart terminés et dans certains cas les stations génératrices attendent depuis plusieurs années la livraison de l'équipement essentiel. L'auteur énonce deux principes de l'utilisation rationnelle de la houille blanche: aucune station thermique ne devra être installée lá où les ressources hydro-électriques sont disponibles; l'énergie hydro-électrique ne devra pas être employée à la production de vapeur ou au chauffage là où des usines thermiques sont en service. Le coût élevé de l'énergie produite par de nouvelles installations hydro-électriques, excédant en certains cas celui de l'énergie thermique, posera des problèmes économiques d' intérêt vital pour les consommateurs privés et certaines entreprises d'exploitation.

Propriétés physiques et résistance des roches au foret (page 252).

Ayant étudié dans un précédent article (page 181 numéro de Mai) certaines des méthodes en usage pour déterminer les propriétés physiques des roches, l'auteur donne ici les résultats des épreuves de dureté faites avec le schléroscope Shore. Il donne un aperçu des appareils employés pour l'étude de la résistance au foret.

L'industrie Hydro-électrique en France. 1ère partie. Par Pierre Chevrier et Stéphane Ferry (page 261).

Cette étude très complète retrace l'évolution de l'industrie hydro-électrique en France depuis son commencement, en 1890, et définit les grandes lignes de son expansion probable. L'accroissement constant de la puissance des génératrices et de l'envergure des projets, aujourd'hui conçus à l'échelle nationale, est caractéristique. La liaison des différents ensembles vise à obtenir, autant qu'il est possible, la régularisation saisonnière; à cette fin, le réseau de transport (150 et 220 kV) a été étendu de 9 000 kms. en 1938 à 14 000 kms. aujourd'hui. Il atteindra dans cinq ans 18 000 kms., avec certaines lignes à 380 kV. Les auteurs soulignent qu'une évaluation correcte des ressources potentielles de houille blanche en France demande une étude détaillée de tous les cours d'eau; cela n'a pas encore été fait. Ils estiment que la capacité totale des installations en service en 1954, lorsque le programme en cours aura été éxécuté, ne dépassera pas le tiers des ressources disponibles. Comme il est probable que toutes les ressources seront exploitées dans l'espace d'une génération, il importe de ne pas sacrifier celles dont la valeur présente est douteuse mais qui peuvent s'avérer précieuses dans un avenir proche.

Construction des barrages en béton (page 268).

La sécurité et la qualité des barrages en béton commandent un soin extrême dans le choix des matériaux employés; tout défaut, en effet, risque d'entrainer des conséquences désastreuses. L'auteur esquisse les deux tests de laboratoire auxquels les agrégats sont soumis, mais il estime que ni l'un ni l'autre, ni les deux ensemble, ne peuvent être considérés comme infaillibles puisque la qualité du béton peut être affectée par un ciment inférieur, de mauvaises méthodes de construction ou une réaction alcaline de l'agrégat. Outre la détermination du poids specifique, les tests d'absorption et de teneur en sulfate de sodium, etc, l'auteur recommande que les éprouvettes soient soumises au gel et au dégel, à l'humidité et la sécheresse et que la dilatation thermique soit étudiée. Il souligne que de faibles quantités de silicate opalin (aqueux amorphe) peuvent causer une expansion excessive et la détèrioration rapide du béton. En ce qui concerne les ciments Portland, certaines spécifications adoptées aux Etats Unis par accord entre producteurs et utilisateurs ont été reconnues par l'American Society for Testing Materials. Un tableau donne la composition de certains de ces ciments.

L'auteur étudie les procédés d'entrainement d'air visant à rendre le mélange plus facile à travoiller et à reduire la quantité d'eau nécessaire à un béton donné, ainsi que l'emploi des pouzzolanes pour combattre la réaction alcaline et réduire le retrait.

Le choix final du mélange ne doit pas être fait avant que la résistance, la pérennite, les propriétés thermiques, le coefficient d'élasticité, les variations de volume et la perméabilité etc aient été déterminés.

Compendio de esta Edición

Recursos de Energía de Finlandia (página 244).

En este estudio tan comprensivo de los recursos hidro-eléctricos del país se pone de manifiesto que las reservas potenciales de la región sud de Finlandia han sido casi completamente utilizadas. Como consecuencia, las compañías generadoras de energía eléctrica se ven obligadas a considerar repetidamente las posibilidades de establecer largas líneas de transmisión procedentes de la región norte del país y de estudiar, más adelante, las posibilidades de aumentar el uso de energía térmica para la generación de electricidad.

Durante los años 1940-1946, sucesivamente se iniciaron once nuevos proyectos hidroeléctricos y la extensión de una central generadora ya existente. Las obras de ingeniería civil en la actualidad han sido completadas en su mayor parte y en algunos casos las centrales generadoras de fuerza motriz han estado paralizadas por espacio de años aguardando la entrega de maquinaria esencial. El autor indica que una utilizacíon racional de la energía hidráulica naturalmente hace presumir que no se utilizarán ins-

talaciones a vapor generadoras de fuerza motriz en los casos en que se disponga de fuerza hidráulica suficiente, indicando además que no se utilizará energía eléctrica para la generación de vapor o para fines de calefacción en los casos en que ya se disponga de instalaciones de energía a vapor en estado de funcionamiento. En algunos casos el elevado precio de la nueva energía hidroeléctrica probablemente que excede el costo de la energía térmica y esto tiende a indicar la creación de problemas económicos de interés vital para los consumidores particulares y para algunas empresas de energía.

Las Cualidades Físicas y de Perforación de las Rocas (página 252).

Después de haber pasado revista, en un artículo anterior (página 181 de la edición de Mayo), de los métodos que se llevan establecidos para determinar las cualidades físicas de las rocas, en la actualidad el autor facilita detales de los resutados de las pruebas de dureza hechas con el Schelorscopio Shore. También describe investigaciones para determinar la dureza de las rocas y facilita una descripción breve de los aparatos empleados para el estudio de las cualidades de perforación.

La Industria Hidroeléctrica Francesa. Parte I. Por Pierre Chevrier y Stéphane Ferry. (página 261).

Se reproduce una descripción muy comprensiva de la evolución de la industria hidroeléctrica de Francia, desde sus principios en 1890 hasta el presente, con una relación de su probable expansión. Se pone de manifiesto que su desarrollo ha sido caracterizado por un aumento constantemente creciente de los grupos de potencia y de la escala en que los proyectos han sido iniciados hasta que, en la época actual, la totalidad del planteamiento es realizado sobre una base nacional. En la actualidad los grandes proyectos son integrados para lograr en la medida máxima posible una regulación de temporada y con este objeto en vista las redes de transmisión (150 y 220 kV) han sido extendidas desde 9.000 kilómetros en 1938 a 14.000 kilómetros en los tiempos presentes. Durante los próximos cinco años esta red será extendida hasta alcanzar 18.000 kilómetros y las líneas funcionarán a 380 kV. Los autores hacen resaltar que el cálculo correcto de las reservas potenciales de energía hidráulica en Francia exigen un estudio muy detallado, el cual todavía no ha abarcado todos los ríos y arroyos. Ellos calculan que en 1954, en cuya época el programa actual tiene que ser completado, la capacidad total de las instalaciones hidroeléctricas en servicio no excederá una tercera parte de los recursos disponibles. Puesto que existe la posibilidad de que los recursos totales sean aprovechados dentro de una generación, debe desplegarse un mayor cuidado para no sacrificar aquellos recursos de un valor actual dudoso que en el porvenir podrían ser de muy gran valor.

La Construcción de Presas de Hormigón (página 268).

Con el objeto de asegurar la seguridad y eficacia de las presas de hormigón es necesario desplegar el mayor cuidado en la selección de los materiales empleados para su construcción, puesto que cualquier falla probablemente llevaría consigo consecuencias desastrosas. El autor hace referencia a pruebas de laboratorio, en las cuales se examinan muestras de mezclas de hormigón con miras a determinar su calidad, pero considera que ninguna de estas pruebas, así como ninguna combinación de las mismas, puede ser considerade como infalible, debido a que el hormigón resultante pued ser afectado por la mala calidad del cemento, métodos inferiores de construcción o reacción alcalina de la mezcla. Además de determinaciones de gravedad específica, pruebas de absorción, buenas condiciones del sulfato de sodio y así sucesivamente, el autor referido recomienda el que se realicen investigaciones relacionadas con el helado y deshelado, humedecido y secado, investigaciones térmicas e investigaciones relacionadas con el cambio de volumen. Hace referencia al hecho de que pequeñas cantidades de sílice opalino (amorfo hídrico) han causado una expansión excesiva y un deterioro rápido del hormigón. Por lo que hace referencia al cemento Portland, en los Estados Unidos de la América del Norte se llevan convenidas especificaciones entre los fabricantes y consumidores, y estas especificaciones han sido admitidas por la " American Society for Testing Materials " (Sociedad Norteamericana para el Ensayado de Materiales). En este artículo se reproduce una tabla indicando la composición de algunos de estos cementos. Se discute el empleo de agentes arrastradores de aire para mejorar el trabajado del hormigón y para reducir los requerimientos de agua de la mezcla para el logro de una masa determinada, al mismo tiempo que se discute la función de puzolanas para combatir las reacciones alcalinas de la mezcla para reducir el encogimiento.

No debería procederse a la selección final de la mezcla hasta que se hayan determinado la resistencia, durabilidad, cualidades térmicas, módulo de elasticidad, cambios de volumen y permeabilidad, etc.

Book Reviews

Optima: *A Quarterly Review. Published by the Anglo American Corporation of South Africa Limited, 44, Main Street, Johannesburg, South Africa.*

This publication, which is to be issued quarterly, is intended primarily for shareholders of the sponsoring companies—notably De Beers Consolidated Mines Limited. It is designed to promote a closer understanding of the diverse factors which influence the shaping of the Corporation's policy. The first issue contains articles which are eminently designed to promote a wider knowledge and appreciation of the activities of the associated companies which have done so much to foster the industrial prosperity of Southern Africa.

Annuaire de la Societe Francaise des Electriciens, 1951 *(1951 Year Book of the French Association of Electrical Engineers), published by Librairie-Imprimerie Gauthier-Villars, 55, quai des Grands Augustins, Paris VI, 8.2 in. by 5.3 in., 260 pp.*

In addition to the rules and bye-laws of the Association, and the list of members and associates, this Year Book gives (p. 245) some information on the " Ecole Supérieure d'Electricité " (High School of Electricity) and its curriculum, as well as on the Central Laboratory of the Association.

From the Journals of the technical institutions and other material published in the Press of the World

New Tunnel for Peruvian Hydro-Plant

The addition of another 60,000 h.p. to Lima Light & Power Co. system involved the driving of an 8-mile conduit, known as the Moyopampa Tunnel, which was completed a short time ago, after 962 days of tunnelling. Six miles of this delivery tunnel are 9 x 12 ft. in section; the downstream two miles are 20 x 16 ft.

The total length was divided into four sections, and an access adit was driven to about the midpoint of each section; when the four adits, totalling 570 ft., had been completed, work on the main tunnel began on eight headings, in both directions from each adit. Drilling was done by means of job-built jumbos mounting four 3½-in. automatic feed drifters. About 150,000 cubic metres of rock were excavated, and 449,200 carloads of muck were hauled out by electric locomotives.

High pressures in the rock caused frequent rock bursts, and excavating was suspended while the dangerous sections were lined with concrete. The narrower section was excavated full face with drilling rounds having from 20 to 32 holes 8 ft. deep, while two-step tunnelling was applied to the 20 16 ft. section, an 8 x 10-ft. pilot bore being first drilled, and then enlarged.

The Moyopampa Tunnel has a 0.275% slope; it leads from Santa Eulalia River to a forebay from which water drops 1,550 ft. to the power house turbines through two 4-ft. dia. penstocks, 2,500 ft. long.

Work started on the S.7,500,000 project in June 1947. The first job was building 12 miles of road, and warehouses and construction camps. Completion is scheduled for next year. — *Enginering News-Record*, Vol. 146, No. 8, February 22, 1951, p. 52, 2 ff.

Volga Development

In addition to the three hydro-electric plants now in operation on the Upper Volga (Ivankovo, Uglich and Shcherbakov) and the Gorki plant, on which construction work started in 1948, two even larger new plants are to be set up in the Kuibyshev and Stalingrad areas. At Kuibyshev the minimum width of the river is 2,200 yards, and the crest of both dams will be three times as wide as those of the plants mentioned above, so as to provide enough room for a broad motor road and a double railway line. The aggregate capacity of the two plants will be 3·7 million kW, and their annual output 20,000 million kWh.

The Kuibyshev plant, on which work appears to be already in progress, is scheduled for completion in 1955; it will supply about 6,000 million kWh per annum to the Moscow industry, while Kuibyshev itself, on the elbow of the Volga, and the industrial centre of Saratov, further south, will receive about 2,500 million kWh. The rest of the output will be allotted to the agricultural districts and to the oil-fields, south and east of the town respectively. This new source of energy will prove highly beneficial to the afforestation of the steppes and the irrigation of the region, but the main purpose of this huge scheme is undoubtedly to satisfy the power requirements of the Soviet armament industry west and east of the Volga.

In contrast to this scheme, the Stalingrad plant is to attend almost exclusively to the irrigation of the region extending on both sides of the river from the Nogai steppe, north of the Azov Sea, to the Ural river. Work at Stalingrad is to begin this year, and the plant is to be completed by 1956. The lion's share of its output, no less than 4,000 million kWh, is again earmarked for the Moscow region, while the rest is to be divided between the central districts of the Black Earth region, the wider areas of Stalingrad, Saratov and Astrakhan, and the territories on both sides of the lower Volga. The Stalingrad reservoir is to ensure the irrigation of a tract of land equal in area to England.

The scale on which these two great plants are projected is perhaps best illustrated by the fact that they will produce together 50 per cent. of the aggregate energy supplied by all thermal and hydraulic power stations in operation in Soviet Russia before World War II. — *E.v.B., Die Wasserwirtschaft*, Vol. 41, No. 3, December 1950, pp. 81/82.

Cathodic Protection at Imperial Dam

The Imperial Dam, on the Colorado River, 40 miles north of the Mexican border, has a battery of 72 desilting clarifiers, each 125 ft. in diameter, and many large drum and radial-type diversion gates. These clarifiers and the gates, together with their control conduits plus the trash racks and other apparatus, constitute a sizeable area of metal. The electro-chemical differences in these metals, in conjunction with the corrosive action of the highly saline water encourages the establishment of electrolytic currents which tend to deteriorate the unprotected surfaces. This process is accelerated at Imperial Dam by warm water temperatures.

Extensive experiments have been carried out by the Bureau of Reclamation with protective surface coatings but the cost, together with the preliminary sandblasting required, amounts to as much as 50 c. per sq. ft. for some of the more inaccessible structures. It was therefore decided to install a cathodic protection system to prevent electrolytic deterioration of the heavy tonnage of metal installed at the Imperial Dam.

This involves the artificial establishment of an opposing current just equal to, or slightly greater than, the current that would be induced by natural means. This current, introduced through artificial anodes (positive poles), flows through the water and soil to the diversion gates and clarifiers, which act as cathodes. Under such a set up, the sacrificial anodes will corrode and eventually decompose.

In the desilting basins, wood poles were jetted into the bottom to support a $\frac{3}{8}$ in. steel cable that serves as a conductor and runs the length of the basin. From the conductor are suspended pieces of scrap steel. Aluminium alloy and carbon anodes are also in use in the protection system. Metal installations outside the desilting basins are protected by additional current-carrying systems.

"Coupons," *i.e.* small, clean steel plates, serve as test pieces to determine the adequacy of the protection. After a year's service, a small deposit of salt has been observed on the coupons, but no trace of rust. The anodes, on the other hand, are rapidly reduced and appear "very rusty."

For the initial installation three-phase, 220-volt rectifier units were secured from Army surplus. The d.c. voltage from these units could be varied from 0 to 20 V. The capacity was about 160 amp. above anything required. At present the current consumed is 1·36 milliamp. per sq. ft. of metal work; this amounts to 90 amp. being applied to 66,000 sq. ft. of metal work in each of the desilting basins.—*Joseph P. Collopy and Waldo D. Freeman, Engineering News-Record,*" Vol. 146, No. 1, Jan. 4, 1951, p. 43, 2 pp., 4 ff.

The New Delhi Conferences

The special issue of *Irrigation and Power*, the Journal of the Central Board of Irrigation & Power in India, published on the occasion of the Fourth Plenary Session of the International Commission on Large Dams and of the Sectional Meeting of the World Power Conference, contains an amazing amount of information of the highest order. This wide range of technical articles, all from the pen of Indian experts, goes a long way to show that the pupil has now hardly anything more to learn from his old teachers in Europe and America. Lack of space unfortunately prevents us from singling out any of these valuable papers for detailed review, we wish however to draw attention to the following which deal with subjects of particular interest to the Water Power Engineer:—

"Modern experimental technique for design of cavitation-free structures," by J. Visweswara Rao, p. 10, 15 pp., 6 ff.;

"Balanced buttresses," by S. B. Joshi and A. N. Joshi, p. 45, 6 pp., 6 ff.;

"Depressing the sub-soil water table by 65 ft. for laying the foundation raft of Sarda Hydro-electric Power Station," by Baleshwar Nath, p. 69, 11 pp., 12 ff.;

"Planning, design, construction and operation of hydraulic models together with economics of model experiments," by Dr. H. L. Uppal, p. 129, 27 pp., 16 ff.;

"Sheet-pile cut off in earth dams," by A. R. Venkatachari, p. 174, 7 pp., 7 ff., 4 tables; etc.

We should also like to mention "Manufacture of Heavy Electrical Equipment in India," by S. Rammohan, of the Central Electricity Commission in Simla, which will undoubtedly prove of particular interest to the manufacturing electrical engineer. In this age of autarky it would be perhaps too optimistic to call Mr. Rammohan's ideas premature: even if India has still a good number of years to wait until she will be able to supply other Asian markets with electrical equipment, we may take it for granted that her manufacturing engineers will not be long to follow in the steps of their research and designing colleagues. (*Irrigation & Power*, Special Issue, January 1951, 184 pp., 101 ff.).

Calculating the Efficiency of Turbines

This article is a reprint of a paper read by the author at the Conference of French Hydraulicians held in Paris in June 1948, and deals with practical applications of Poirson's method of calculation which is based on the fact that, in a water turbine, the amounts of heat corresponding to power losses are used to raise the temperature of the water which acts simultaneously as a cooling agent and a motive fluid. It is claimed that, by this method, it is possible to ascertain the efficiency of a turbine by measuring two differences in temperature without taking the discharge into account, this efficiency being expressed by the formula

$$\eta = \frac{O'_2 - O_2}{O'_2 - O_1}$$

in which O_1 is the temperature in °C. at the intake, O_2 the temperature of the water passing from the turbine into the tail-race, and O'_2 the temperature of samples of water drawn at the entrance into the turbine.

Proceeding from this formula, and by adding to the measuring arrangement a resistance placed in the tail-race, the efficiency of the alternator driven by the turbine is expressed by

$$\eta \text{ alternator} = \frac{O_3 - O_2}{O'_2 - O_1}$$

in which O_3 represents the temperature of the water measured downstream from the resistance, and the overall efficiency of the set is expressed by

$$\eta \text{ overall} = \frac{O_3 - O_2}{O'_2 - O_1}$$

The author lays particular stress on the measurement of water losses in the labyrinth seals of Francis turbines by the same method which, he claims, is the only method which, at the present time, permits to assess with a fair degree of accuracy the extent of these losses. (M. Fontaine, *La Houille Blanche*, Vol. 6, No. 1, p. 12, 11 pp., with a summary in English p. 20).

Behaviour of Large Thrust Bearings in Operation

In this extensive and most interesting article the authors, both on the staff of the well-known *Etablissements Neyrpic*, describe in detail the tests they carried out in order to ascertain the behaviour of such large thrust bearings as those now in common use in modern

water turbines during the critical periods, *i.e.* starting and stopping, and to establish the influence of the distortion factors affecting sliding surfaces at full speed.

After emphasizing in a short introduction the importance of accurate designing, machining and regulating of such bearings, the authors review the measuring methods applied by various other experimenters, with a view to determining either the transition from the dry or semi-fluid to the hydro-dynamic stage or the influence of distortion factors affecting the sliding surfaces. In the former connection they lay particular stress on the measuring methods used in order to ascertain the thickness of the lubricating film but add that these measurements can only reach their full value in both practice and theory if they are supplemented by measurements bearing on the various ways temperature and pressure are distributed on the sliding surfaces.

In its second part, the article deals first with the essential characteristics of thrust bearings, then describes the thrust bearing tested, and finally reviews summarily the results of the various tests, as carried out at the different stages:—starting, full speed, and stopping. The measurements at the starting stage bear on the friction couple and the thickness of the oil film; at full speed, the thickness of the film, the superficial temperatures of the sliding surfaces, and the pressures; the measurements connected with stopping are:—the friction couple, and the thickness of the film.

The authors conclude that the range of measurements effected established that the thrust bearing tested (fitted on one of six identical Francis turbines at the Lower Drac hydro-plant near Grenoble) worked in a faultless manner. After numerous starts and stops the sliding surfaces showed but a few scratches of about 1 micron, though traces of scraping were visible all over the surfaces. It is obvious that such favourable results cannot be expected in all sizes of thrust bearings. Should the sizes at present in use be increased, it would be necessary to improve their design so as to ensure just as perfect an automatic distribution of the loads as available in the bearings now in operation. A comprehensive bibliography accompanies this article. (S.-X. Casacci & A. Peuchmaur, *La Houille Blanche*, Vol. 6, No. 1, p. 23, 21 pp., 21 ff.).

Increasing the Economic Value of Hydro-electric Power

The author discusses in this article the possibility of increasing the economic value of hydro-electric power by utilising off-peak current for the production of various highly valuable commodities such as petrol substitutes (methane), acetylene, ammonia, and even steel.

In India water power is regarded as a by-product of irrigation. When power is generated exclusively for heating and lighting purposes, as well as for railway and rural electrification, the load factor, *i.e.* the ratio of average to maximum power consumption rarely exceeds 60%. In the case of water power the advantage increases as the load factor rises or, in other words, the utilization of off-peak current not only brings about a higher economic value of hydro-electric power but is also likely to encourage the harnessing of more water power.

The advantages of an expanded utilization of off-peak power is examined separately in connection with the production of each of the four commodities mentioned, and the author is of opinion that it is possible to increase the load factor from 60 to 100% on an aggregate amount of 2.14 million KW-years of hydro-electric power.

This would not only make the electrification of railways, as well as rural electrification, commercially more attractive and profitable but would also, at the same time, contribute to meeting the demand for steel, ammonia, acetylene and liquid fuels with a net saving of 29.4 crores of Rupees per year, mainly by cutting down fuel, lime and other requirements. (V. Aravamuthan, B.Sc., A.Inst.F. (London), *The Central Board of Irrigation Journal*, September, 1950, Vol. 7, No. 5, p. 502, 5 pp.).

Checking Seepage in an Old Dam

De Ruyter Dam and Reservoir were set up near Syracuse, N.Y., in the years 1861-63 for storing feeder water for a high-level length of the old Erie Canal near Rome, N.Y. This veteran structure developed increasing seepage troubles which resulted in piping, and leakage became so bad that several slides occurred on the downstream slope of the dam.

The structure has about outlived its intended use but the Authority responsible—the N.Y. State Dept. of Public Works—is apparently anxious to preserve the reservoir, in the first place for recreational benefits and, as a remote secondary possibility, for feeding the N.Y. State Barge Canal.

Steps are therefore being taken to save the dam at the lowest possible cost. After all possible methods of stopping seepage had been investigated it was soon established that no upstream cut-off could correct the existing saturation, and the solution finally adopted consists in tackling the problem from the downstream side by helping the water through the structure while, at the same time, ensuring its stability.

Some 1,350 ft. of underdrains are being buried in the completely saturated downstream slope, which will be further stabilized by a surcharge of dry soil to balance upward seepage forces. The drains consist of half-circular-section vitrified clay pipes 12 in. diam., 2 ft. long, with bell-and-spigot joints; the bell halves of these joints have lugs that prevent tight fit, thereby making it an open-joint line for underdrain use. The top of these pipes is slightly concave, so as to act as a channel to carry water to the next open joint. Manholes made of precast reinforced concrete pipe 4 ft. diam. by 3 and 4 ft. long, are provided at all drain junctions and changes. Lids for the manholes are circular precast concrete slabs with round access openings to be closed by removable C.I. covers. These manholes had to be extended up high enough to clear the surcharge fill which will stretch over a 450-ft. length of the embankment, and be 185 ft. wide at its greatest width, its height varying up to 18 ft. The valve-house walls at the downstream toe must be heightened to clear this new surcharge. Present repairs do not require the lake to be drained: its level has only been lowered 12 to 13 ft. below spillway crest. (*Engineering News-Record*, Vol. 146, No. 4, January 25, 1951, p. 39, 3 pp., 9 ff.).

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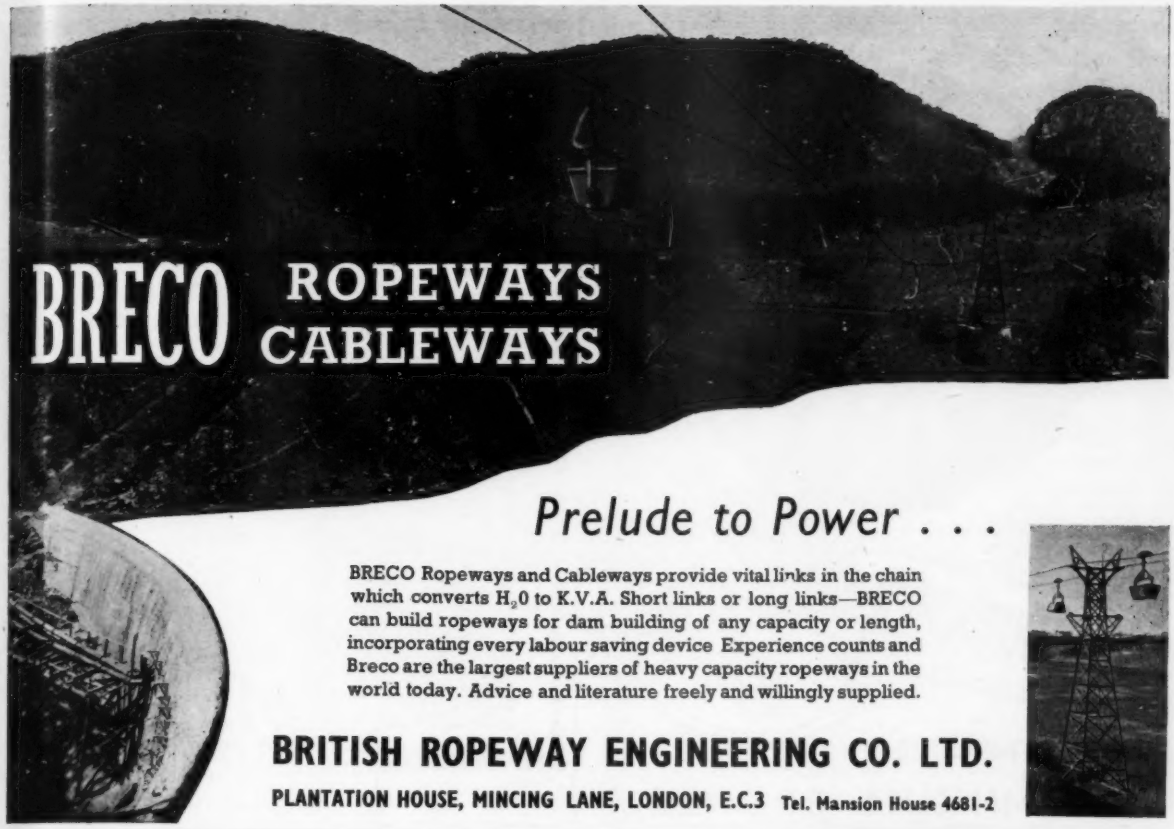

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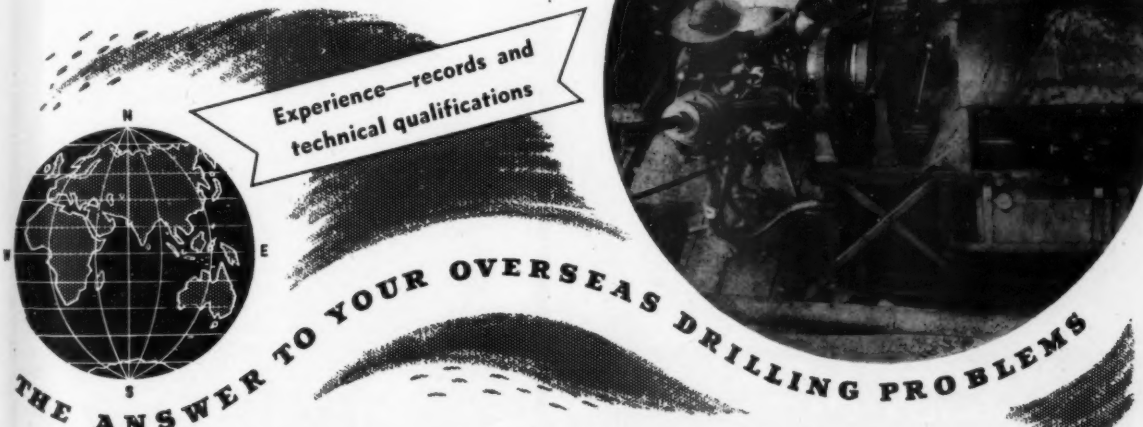

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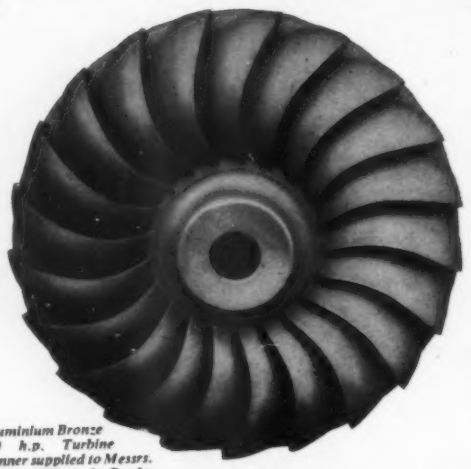

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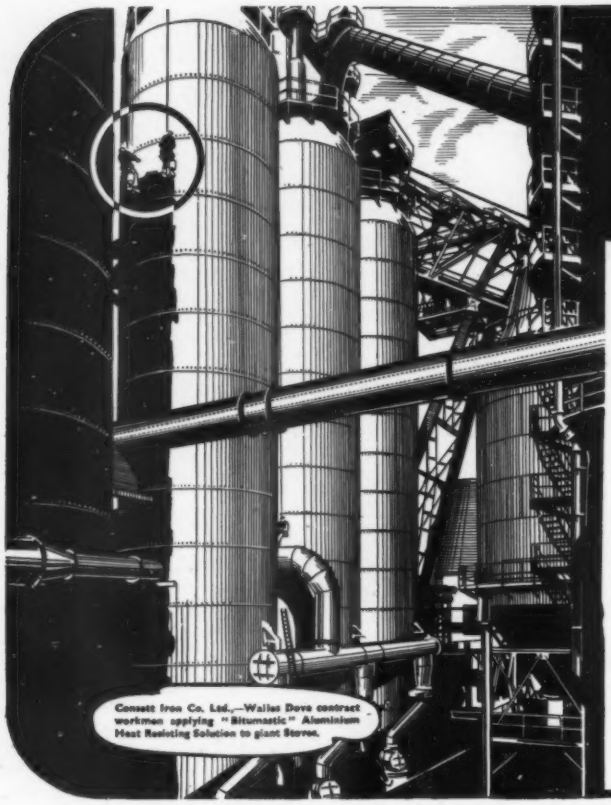

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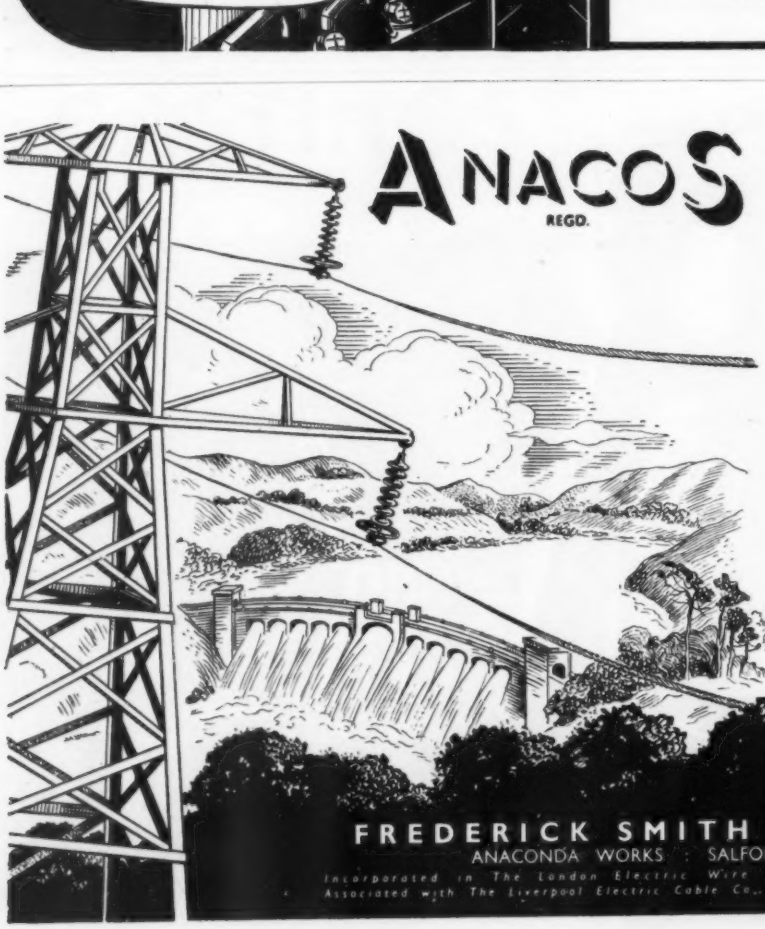

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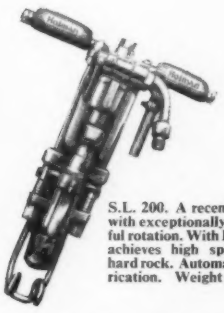

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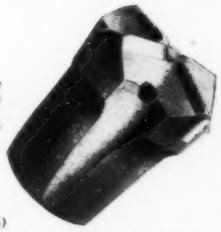

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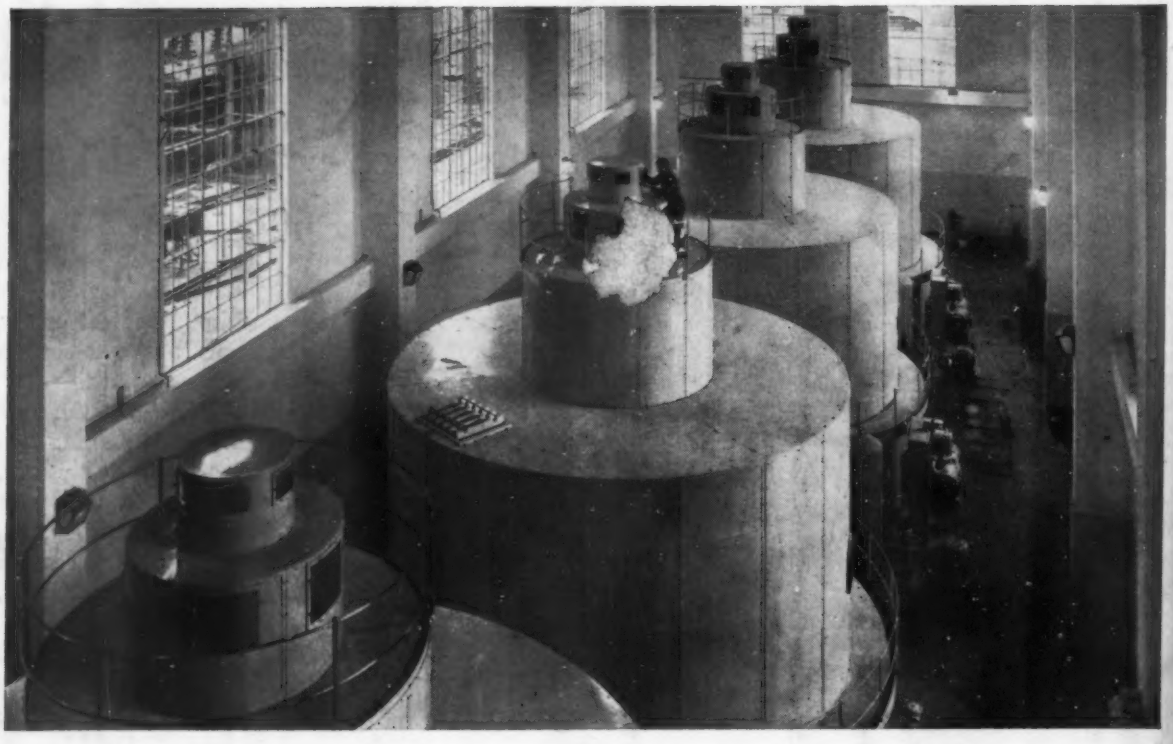

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